Show & Tell
What Fun Can Do

A Major Qualifying Project
Submitted to the Faculty of
Worcester Polytechnic Institute
in partial fulfillment of the requirements for the
Degree in Bachelor of Science
in
Mechanical Engineering
By

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Submission Date: 4/25/18
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Abstract

‘Umwelt’ is a German word meaning “environments,” or “surroundings.” In English, we use the word to describe the world as it is perceived by a given organism. Different organisms have Umwelts of different sizes because they rely on varying degrees of one or more senses to interpret their realities. As sighted people, we can *only imagine* the disconnect that arises when another person’s Umwelt doesn’t include sight.

As humans, we can connect *fellow humans* to the world that they do not know exists around them through the use of play, and in the process, more intimately include them in society. 80% of the information sighted children learn from the world comes from their vision, which causes a substantial disconnect between blind and sighted children. Play is also crucial to cognitive, social, and emotional development. Toys for blind children are overpriced, under-designed, and fail to use current technology. The result of this project was the design of a fun, educational, reasonably priced toy for blind children.

Acknowledgements

Paul Cotnoir, John Rochford, Dequindre Cummings, Matthew Hopkins, Becker game design students

Executive Summary

In the Assistive Technology (AT) industry, toys for disabled children are often overpriced, under designed and seldom readily available. These toys are more like tools than a source of fun and the lack of fun toys for disabled children threatens their ability to play. Play deprivation can cause serious developmental problems in children. The goal of this project is to design a toy for the visually-impaired that acknowledges the shortcomings currently present in the AT toy market. With a high priority on fun and replay value, and after literary and first-hand research, several product design concepts were developed to achieve this goal. Through the analysis of these potential solutions, the Show & Tell was determined to be the most viable. Through demonstrations and focus groups the design was evaluated and was shown to successfully accomplish the defined goal.

Two prototypes of the Show & Tell were manufactured to test both the mechanical design and the game development aspects of this product. The Show & Tell consists of a base unit, five tile buttons, one central menu button and five tiles with textured artifacts. The tiles and artifacts, along with software contained on a USB thumb comprise a play pack, of which several will be available, give the user information and prompts from the game via haptic feedback, stereo audio, and tactile artifacts. The unit also has a volume controller and power switch which are easily identifiable and understandable to visually impaired users. The player loads in a game by inserting the USB flash drive with the game data into the USB slot located on the front face. The game is specific to the tiles which come packaged in a particular play pack. A play pack consists of a set of five tiles and a USB drive to load the game specific to those tiles. The Show & Tell incorporates a universal design and infinite expandability, making it fun and playable by disabled and nondisabled individuals for much longer than a traditional toy of this nature. Given the nature of the device, it can be distributed in a traditional toy market place like Target or Amazon, but it can also be distributed through organizations that focus on the empowerment of the blind and visually disabled, such as Perkins School for the Blind.

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Chapter 1: Introduction

1.1 Problem Statement

In the Assistive Technology (AT) industry, toys for disabled children are often overpriced, under designed and seldom readily available. The toys are often designed with the intention of being used as developmental tools rather than a genuine source of fun and enjoyment. In addition, disabled children are often underestimated in their capacity for understanding resulting in the quality of design for these toys suffering. Simply put, the current AT market does not provide the proper support needed for individual growth in disabled children. Every child can be impacted positively by toys and disabled children are no different.

1.2 Goal Statement

The goal of this project is to design a toy for the visually-impaired that acknowledges the shortcomings currently present in the AT toy market. Tailored to children ages 6 to 12, the design should capitalize on the individual’s tactile and auditory senses as a vessel for a fun, interactive and developmentally positive way to play alone or with others. Its universal design allows for play among varying skill levels, ages and abilities regardless of the demographic. Play value is reinforced through an open source method of approach, effectively making the game limitless in gameplay variety and potential.

1.3 Design Philosophy

You can see a fish that you've never seen before, and you would know it was a fish. Using your eyes, your mind is able to almost instantaneously collect infinite amounts of information-- say, about a particular fish's shape, texture, proportions, geometries, and general likeness-- and add it to its constantly evolving definitions for what a fish is.

Those constantly evolving definitions are the easy part, though. They're like adding additional rubber bands to an already formed rubber band ball. And that process can be likened to the processes that we, as sighted humans, use in any given moment when (1) our eyes are open and (2) we are navigating, interpreting, or otherwise aware of our existence because of information that has come to us through our eyes.

When you meet something that is new to you, your eyes not only take in an inconceivable amount of information, but they also begin to draw infinitely many conclusions using the visual information that has been presented to them. This process happens constantly, at a speed/rate that is only limited by our perception of it.

'Umwelt' is a word of German origin meaning "environments," or "surroundings." Today, the word is used to describe the world as it is perceived by a given organism. Which is to say, that different organisms have Umwelts of different sizes because they interpret their realities using not only varying degrees of the same senses, but also totally different ones.

The way in which we interpret the outside world is absolutely core to our being. Yes, as individuals, but more importantly as humans. In the culmination of evolution that is our biomechanical design, we are meant to interpret reality, at least in part, using our eyes. As sighted people, we can literally only imagine the disconnect that arises when another person is unable to experience a sense that otherwise would have contributed to the size of their Umwelt.

As sighted people, we have a perspective on reality that those without sight do not, and as people in STEM, we have the ability to close that gap. More importantly, as humans, we have the ability to connect *fellow humans* to the world that they may not know exists around them, and in the process, to more intimately include them in the fabrics of society.

We live in a day and age where ideas are powerful. Because of technology, nearly any idea can be acted upon. In and of itself, we believe that engineering a toy that serves as a vehicle for this idea has the potential to make a positive impact on society.

Chapter 2: Background Research

2.1 Identify Lead Users

The first step in concept development lies in the identification of the target audience. The questions that will be asked pertain to a variety of different factor including, but not limited to, target population, market reach, availability and diversity, purchasing power, etc. All play a role in identifying the goals and objectives intended for the toy being created. Furthermore, the choice to appeal to such a small demographic can prove troublesome in revenue sales. To address these issues, further research is needed to analyze the exact needs of the target population. The following section will address aforementioned concerns and impediments.

According to the American Community Survey results from 2015[1], 12.6% of the United States population was affected by some sort of disability, 12.6% translating to approximately 40,710,600 people. Furthermore, of those approximate 41 million people, a total of 7,297,100 people were non-institutionalized males and females (of all ages) living with a visual disability. Nearly 7.3 million people equate to 2.3% of the total US population. Although this is a relatively small percentage, one must consider the potential impact of this demographic.

Take into consideration the total number of visually disabled persons enrolled as full-time students that year. Referring to the American Community Survey once again, there was a total of 678,000 non-institutionalized males and females of all races, ethnicities and education levels that were between the ages of 4 and 20 that reported some sort of visual disability[2]. It is important to consider the consequences of neglecting such a demographic, including those with developmental

[1] Erickson & von Schrader (2016)
[2] Erickson & von Schrader (2016)

and behavioral abnormalities. There has been research showing that neglect of disability related issues by caretakers and parents can leave a long lasting negative impact on the child. Therefore, it’s better to address their concerns early on rather than letting the issue progress.

Throughout human development, the mind is susceptible to educational and situational learning. While education proves to be extremely important when pursuing higher levels of learning, situational learning is a key part to an individual’s integration into society. A large portion of social skills/cues are derived from our physical senses (touch, taste, hearing, smell and sight). Taking one away can have a large impact on the way one communicates to others. Without the sense of sight, one can no longer read body language or facial expressions, which are significant factors when communicating with another human being. This can prove troublesome to one’s development. Without the ability to properly communicate with another human being, those with disabilities (visual impairment in this case) struggle to communicate with their peers, often being ostracized as a socially inept individual[3].

Those with disabilities need the proper educational and social support systems in order to compensate for skills otherwise acquired by other more conventional means, not to say they aren’t capable, simply restricted. Of the 62,528 students with a reported visual disability, 5,116 (8.2%) enroll in residential schools for the blind, culminating in the 2nd largest portion of visually disabled students pertaining to a specific educational system. However, the largest portion belongs to the state departments of education totaling to 52,003 students, meaning that 83.1% of all visually impaired students are enrolled in the public education system[4]. Although, due to the additional resources required to accommodate these students, most public education systems don’t have the financial security to purchase supplementary Assistive Technology (AT) or hire specialized

[3] Missiuna, C., & Pollock, N. (1991)
[4] Statistical facts about blindness in the united states (2017)

faculty. While the aforementioned resources may be considered materialistic, their absence can seriously hinder the education and social development of these students.

Further addressing resources that the visually impaired require, it is also important that the children are exposed to a broad range of unique toys to help instill creativity and develop a variety of different sensory skills through repeated play and practice[5]. As for choosing a toy for a child, disabled or not, it is beneficial to analyze the potential for positive growth in a child's development. This is especially true for younger children. For most children, there are approximately ten skills that can be prioritized in order to further assist in the child's development of cognitive, social and physical skills. Those ten skills are: auditory, creativity, fine motor, gross motor, language, self-esteem, social, tactile, thinking, and visual[6]. These skills overlap for both disabled and non-disabled children.

When purchasing a toy for an able-bodied child, it is often of primary importance to consider the age-appropriate interests of the child in order to select the appropriate toy for him/her. This may include toys from their favorite cartoons, shows, sports, books, and movies. However, due to the underestimation of the capacity of disabled children, their interest often goes unnoticed and unrecognized in the toys currently available on the market. Including these themes are simple and can further increase interest in the toy and product continuity. It is a fantastic way to draw the attention of children whilst also providing a vessel to hone their skills, whether it be cognitive, social or physical. An example of these toys would be the *Little Tikes Light n Go 3-in-1 Sports Zone* (see figure 1).

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[5] Market value of U.S. toys and games market 2005-2017 | statistic. (2018)

[6] Toy guide for differently-abled kids. (2018)

Figure 1 Little Tikes Light n Go 3-in-1 Sports Zone

This toy combines three different sports into one, presenting a basketball hoop, a soccer net, and a rack of bowling pins. In addition to developing gross motor skills, the toy also promotes the development of visual and auditory skills. This is done through an educational feature which assists children with learning shapes, numbers, and colors. The *Hape Pound & Tap Bench* shown in figure 2 is another toy that also promotes the development of younger children. The toy promotes fine motor and auditory skills as it presents both a xylophone and percussion set in one toy. The child is able to play by practicing their recognition of audio cues and fine motor skills through the use of instruments. As children mature, and their talents develop beyond the skill level of their toys, they will tend to lose interest in those toys, and the toys become ignored, broken, or discarded.

Figure 2 Hape Pound & Tap Bench

2.2 Identify Market reach

Oftentimes potential marketability is what determines the feasibility of a design. In addition to the need for a product that solves the problems identified above, it can also be said that there is an active industry that revolves around the visually impaired and that they command notable buying power.

Admittedly, nearly all statistics on the blind are extrapolated from sample populations. Agencies such as the Bureau of the Census, the National Center for Health Statistics, and the Bureau of Labor Statistics all use techniques that ultimately rely on extrapolation. Even so, there are a number of statistics that have been reported by federal and independent organizations. Developing a toy for visually impaired children should take into special consideration three factors: (1) the number of children who are enrolled in some type of schooling program, (2) the number of children who cannot attend school, but still have a need for developing social, emotional, and intellectual skills, and (3) a parent's purchasing power, and desire for their children to grow.

Vision impairment can be described as having trouble seeing: the inability to recognize a friend across the room or the inability to read regular newspaper print, even when wearing glasses, and it includes blindness in one or both eyes. There are an estimated 1.4 million children age 14 and under in the world classified as blind (Thylefors, Négrel, Pararajasegaram, & Dadzie, 1995), and there are an estimated 448,000 children with vision impairment in the U.S. Out of these children, there are roughly 264,000 children 6-14 years of age who have difficulty seeing words and letters in ordinary newsprint even when wearing glasses or contact lenses, and roughly 45,000 children with severe vision impairment where they were unable to see words and letters in ordinary newspaper print according to data from the Survey of Income and Program Participation (1997). This leaves 219,000 with a non-severe vision impairment (McNeil, 2001). To gain a sense of the population size of visually-impaired children, we collected research on other age groups as well. For younger children, ages 5 and under, there was data collected in 1990 on legal blindness that indicated that approximately 2,600 children were legally blind, and for adolescents between the ages of 5 and 19, there were approximately 51,000 who were legally blind (Chiang, Bassi, & Javitt, 1992).

There is a growing population of children with vision impairment. According to Prevent Blindness America, twice as many people will be blind in 2030 as there are today (Prevent Blindness America, 1998-2000). These demographics show that there is a population of children with vision impairment who can benefit from our project goal of creating a device to capitalize on their senses of touch and hearing as a fun and interactive way of learning.

The American Printing House for the Blind has an annual responsibility to poll each state for the number of children who are legally blind— that is, under the age of 21— and enrolled in a U.S. elementary or high school. Their results are then used to calculate the amount of federal taxpayer dollars that are allocated on a state-by-state basis to provide reading materials in accessible formats. Because of this process, their statistics on these demographics are some of the only *exact* figures that exist. In addition to polling schools for populations, they also poll the students on their primary reading medium.

In 2015, Cornell University's Yang Tang Institute (YTI) conducted a survey to find the number of non-institutionalized male and females individuals between the ages of 4 and 20 who reported a visual disability in 2015. There were no divisions made on the basis of their education levels. The YTI found that there were approximately 678,000 such people representing 0.78% of the American population. Of them, approximately 324,000 were female and 354,000 were male.

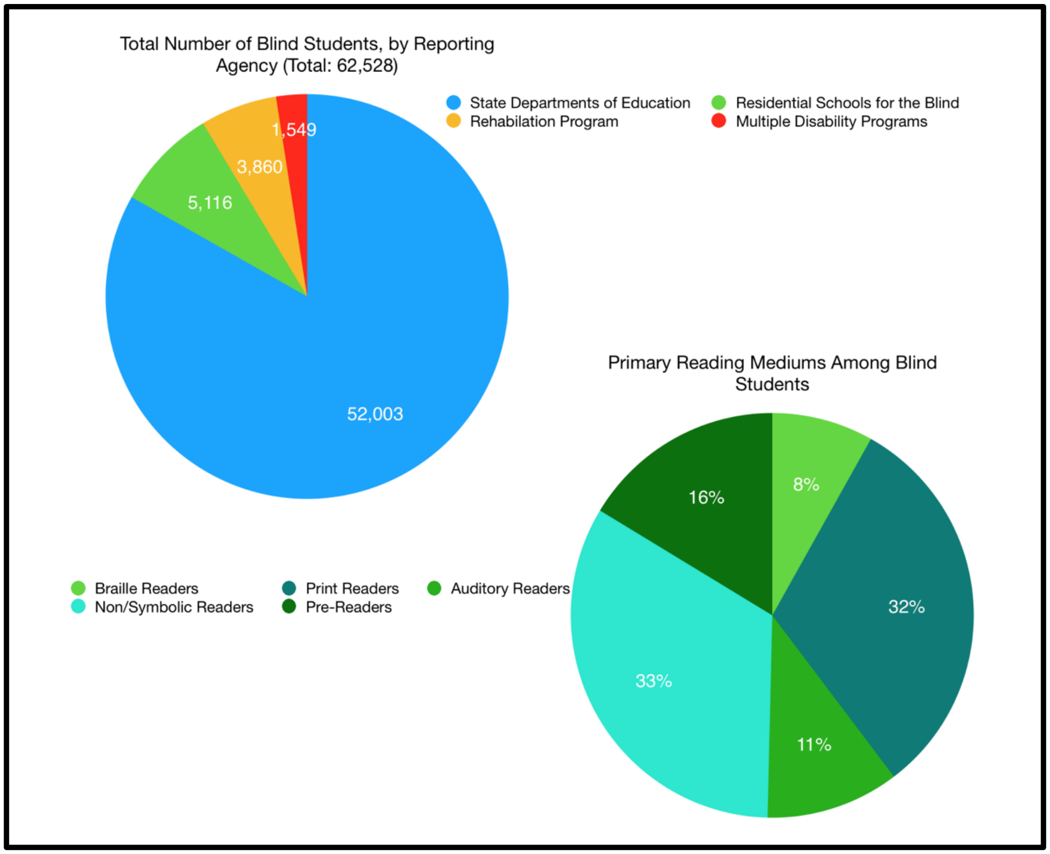

Figure 3 Statistics on Blind Students

To only take into consideration the economic impacts of the blind, their supporting organizations, and the assistive technology industries would be an incomplete analysis. It is at the intersection of those industries *and* the toy industry— which represented $20.36 billion of spending in 2016, a 5% increase from 2015 which saw a 7% increase from the year before— where the potential for both market disruption and the ability to create something impactful exists.

Making our product feasible for different environments is important as our target audience includes both parents of children with vision impairment and schools or educational programs for children with vision impairment. Understanding how many visually impaired children attend school can help us estimate the market for our product. According to the State reported data to the Office of Special Education Programs, 26,070 students age 6-21 received vision services under IDEA during the 1997- 1998 school year (U.S. Department of Education, 1999). Among students who have disabilities, students with sensory impairments are the most likely to graduate from secondary school with 73% of those with visual impairments doing so (based on data from the 1993-1994 school year (Kaye, 1997). Additionally, there are an estimated 4.5 million children around the world without access to education due to blindness, therefore there is a need for this type of educational device.

We plan to incorporate braille into our design so it is important to gauge how many children have learned braille. According to the American Printing House for the Blind (1999), approximately 10% of blind students (5,557) primarily use Braille and 25% primarily use large or regular print (14,571).

Studies show that braille instruction for a blind student is equivalent to literacy instruction for a sighted student, and that braille is a critical literacy tool for anyone with vision impairment. It is believed that a few decades of misguided attitudes about braille instruction have deprived visually impaired children of this useful tool for education. For children who are visually impaired to have the same learning experiences, they must be exposed to the world around them in ways that will enable them to learn through their other senses. As a result, children who are visually impaired often have differences in learning style. For example, learning without sight takes more time because they need the time to explore objects physically that sighted children can take in at a glance, and they need help integrating what they experience by touch with what they hear, smell, and taste. Generally, a visually impaired child also needs one-on-one time with an adult to hear the names of objects, although they may learn to tune out any language they do not understand from experience because it is based on what the speakers have seen and it does not make sense to them.

2.3 Psychology of Play and Gamification

"Gamification" is an umbrella term for the use of game elements in non-gaming systems to improve user experience and user engagement. Bernard Suits, philosopher, defined playing a game as the following: "Playing a game is the voluntary attempt to overcome unnecessary obstacles." Games are motivating and rewarding and fun. Games evoke a feeling of happiness in the players because they give tasks which the player chooses to complete and require hard work[7]. Although play and work seem to be on opposite sides of the spectrum, humans get much satisfaction from completing hard task.[8] Brian Sutton-Smith, a leading psychologist of play, once said, "The opposite of play isn't work. It's depression."[9] During gameplay, while overcoming unnecessary obstacles, the player becomes intensely engaged and the attention systems, reward center, motivation systems, emotion center and memory center becoming fully activate.

All games share common attributes: *a goal, rules, a feedback system, and voluntary participation*. The **goal** is the specific outcome that players will work to achieve, giving the game a sense of purpose while grabbing their attention and orienting their participation. The **rules** remove or limit some of the obvious ways to get the goal, so creativity and strategy are used to come up with outside the box solutions. The **feedback** system lets the players assess their

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7 Suits, B. (2014).
8 Deterding, S. et. al.(2011)
9 Marano, H. E. (1999)

progress in achieving the goal. This could be a point system, score, progress bar, etc. also the feedback ensures players that the goal is achievable, and it provides motivation to keep playing. Finally, **voluntary participation** requires that everyone who is playing the game knowingly and willingly accepts the goal, the rules, and the feedback. And the freedom to enter or leave a game at will ensures that intentionally stressful and challenging work is experienced as safe and pleasurable activity.[10]

These are the four major game design elements when considering gamification. Although games have many different components and attributes like interactivity, graphics, narrative, rewards, competition, virtual environments, or the idea of "winning", these elements are just placing emphasis on the four main elements.[11]

When gamifying a non-gaming system, it is important to consider the target group. The audience for the gamified system will determine the type of design elements to incorporate. For the gamification of an educational system adding a narrative is useful to orient the player towards the goal. The ability to level-up and/or master certain things will keep the motivation to continue high. Opportunities for collaborative problem solving and social connection can also be effective attributes to include when gamifying learning. Teaching students that everyone has special super powers or personal strengths that will help to achieve goals will engage them in the narrative. By incorporating choices into the learning creates a sort of voluntary attempt to overcome the obstacles. Another way to keep the target group engaged in an educational setting is to incorporate bonuses and/or 'Easter eggs' where spontaneous benefits arise.[12]

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[10] McGonigal, J. (2011)
[11] Wiklund, Emil (2016)
[12] Quest to Learn. (2016)

Quest to Learn, an institution that focuses on gamifying education, defines games as "carefully designed, student-driven systems that are narrative-based, structured, interactive and immersive." Quest uses games because they encourage collaboration with others and learning by doing. Other benefits are that the player know if they are failing or succeeding and allow us to retry, or "iterate," after a failure or loss. [13]

According to Quest to Learn, the seven principles to game-based learning are (1) Everyone is a participant, (2) Challenge, (3) Learning happens by doing, (4) Feedback is immediate and ongoing, (5) Failure is reframed as "iteration", (6) Everything is interconnected, and (7) It kind of feels like play.

If everyone contributes different students can contribute different specialties. A "need to know" challenges students to solve the problem with the tools at their disposal. Students learn by proposing, testing, playing with, and validating theories about the world. receiving feedback on their progress, learning, and assessment goals lets students see where they stand. Failure should be seen as an integral part of learning and all learning experiences should embrace a process of testing and iteration. Students can share their work, skill, and knowledge with others across networks, groups, and communities keeping the learning experiences engaging, student-centered, and organized.[14]

Compared with games, reality is disconnected. Games build stronger social bonds and lead to more active social networks. The more time we spend interacting within our social networks, the more likely we are to generate a subset of positive emotions known as "prosocial emotions." Gamifying an educational system can give a sense of ownership over the learning and

[13] Quest to Learn. (2016)
[14] Quest to Learn. (2016)

the freedom to fail and try again without negative repercussions. This also allows opportunities for identity work through taking on alternate selves such as in the superpowers case.[15]

When designing a game or toy it is important to consider what it means "to play" to investigate the toy's play value. The definition of the term play is not particularly concise and varies depending on the context of the situation; however, according to Dr. Peter Gray, Ph.D. a research professor at Boston College, many of these definitions can be condensed to the following five attributes: (1) Play is self-chosen and self-directed; (2) Play is activity in which means are more valued than ends; (3) Play has structure, or rules, which are not dictated by physical necessity but emanate from the minds of the players; (4) Play is imaginative, non-literal, mentally removed in some way from "real" or "serious" life; and (5) Play involves an active, alert, but non-stressed frame of mind. It is important to understand that play is an expression of freedom in that play is something that is done willingly and without obligation.[16] Beyond the free choice to engage in play, it is equally as crucial for players to feel the liberty to quit or stop playing. Gray believes that "A person who feels coerced or pressured to engage in an activity, and unable to quit, is not a player but a victim."[17]

In play, value comes from the means, not the ends of the activity; Players might not seek the easiest means to an end but rather savor the process. It is helpful to consider the following comparison of a cat *preying* on a mouse versus a cat that is *playing* at preying on a mouse. The cat that is preying on the mouse takes the quickest route for killing it; whereas the playful cat tries several approaches to catching the mouse, not all very efficient, and lets the mouse go each

[15] Quest to Learn. (2016)
[16] Gray, P. (2017)
[17] Gray, P. (2008)

time so it can try again (replay). In this analogy, the former cat enjoys the end and the latter cat enjoys the means.

Although play is a freely chosen activity, it always has some form of structure. This structure is rooted in the rules of the game and these rules are the means by which one plays. The structure of play is the concepts that require conscious effort to follow. For example, a basic rule of play for building blocks, is that you must work with the chosen medium. Whether the goal is to build a model of something specific, or to bring an abstract design to life, you are limited to the shape, size, and quantity of the building blocks at your disposal. The structure of this type of play is that you must use the limited medium of the blocks in order to represent a more complicated idea.

Lev Vygotsky, a Russian developmental psychologist, points out an apparent paradox with play: In play one enters a realm that is physically located in the real world, makes use of props in the real world, is often about the real world, is said by the players to be real, and yet in some way is mentally removed from the real world.[18] Imaginative play is most obvious in socio-dramatic play, where the players create the characters and plot. Socio-dramatic play is the most advanced form of social and symbolic play allowing children to carry out imitation and fantasy play involving role-playing. This disconnect from reality is present in all forms of play and is heavily related to the rules involved. In the fantasy world of chess, for example, bishops can only move along the diagonals, yet in the real-world bishops can move in any direction they choose.[19]

The mental state of play is very important when considering play as a mode of learning or creative production. The alert but unstressed condition of the mind during play is ideal for

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[18] Vygotsky, L. S. (1967)
[19] Gray, P. (2008)

creativity and the learning of new skills. Gray comments on psychological experiments correlating strong pressure to perform well (a stressed state of mind) *improves* performance on tasks that are habitual, but *worsens* performance on tasks that require creativity, decision making, or the learning of new skills. In contrast, reducing the person's concern with outcome and increasing the person's enjoyment of the task (increasing the play value) has the opposite effect on the subject. It is important, however, to maintain the understanding that play must require an active, alert mind. When an activity becomes too easy or habitual, and no longer requires conscious mental effort, it may not be considered play. Making the goal more difficult to accomplish can keep the players mentally active and engaged in play.

From this research we have determined that there are several design characteristics that must be considered to develop a fun toy for our target audience.

- Fun: First and foremost, our toy must be fun with play value as the chief driving force and any developmentally positive features being on the back burner of the design. The goal here is to add to the market something that does not yet exist: a toy for visually impaired children that is fun with no ulterior motive.
- Accessible to the visually impaired community: To design a product for a population with a disability, one must first understand the disability and the implications of living as a member of this community. With visually impaired youth as our target demographic, we can assume that the only difference in the capabilities of this group and sighted you is in the primary senses with which they interpret the world around them. In doing this we must design a toy that capitalized on some of the other senses such as touch and hearing.
- Accessibility and ease of use for children: as mentioned previously another consideration that must be considered in our toy is that it is easy to use for a child's ability. This is

referencing both mental and physical prematurity of children. To address this our design must be dimensioned such that any piece that is meant to be handled must be small enough to be compatible with the smaller hands and short reach of children. In considering the mental development of children we must be sure to adapt any interactions (output information, vocabulary, comparisons, decision making, attention span, etc.) to be digestible for our target audience.

- Universal Design: Although the target audience for this product is visually impaired youth, it is important for our design to reach beyond that scope. By broadening our horizons and designing a toy that is fun and accessible for blind children *and* sighted children alike, the product will be able to be marketed and sold to a larger audience correlating to more units being sold and reduced manufacturing cost per unit.
- Expandable: our design will be expandable allowing for additional content. This is to increase the replay values of our toy. Our design should allow the user to play through completely and then have the option to get additional content which either modifies the original play or add an entirely new element to the game (even adding entirely new games and game modes to the device). In making our toy expandable we can effectively reduce the buy-in cost for the customer since they would no long need to buy a toy with several features but can buy a stand-alone system and then continually invest into maintaining the play value rather than letting it decrease with play cycles.
- Open source: In trying to keep our product affordable, we want to enable the customer to keep getting value out of their money even after they have already purchased our device. We plan to do this by making some of the features of our design available for download. We play to have the .STL files for any parts that can be 3D printed at home available for

download. We plan to also upload any data files that would be necessary for expansion. This means that if a user has already purchased the main component of our product, they can opt to save some money and manufacture their own additional content.

Chapter 3: Methodology

3.1 Need Statement

Before looking into the development of the initial concept, there was a need to identify not only the targeted demographic, but the needs present in their environment that must be addressed as well. The demographic chosen to be addressed are children currently living with visual-impairments or blindness. Finding a manner to address the issues presently affecting the blind community is a cumbersome task more easily said than done. There was a need to think of a variety of factors that impact the addressability of the problem at hand, being, that blind children simply aren't provided toys stimulating or fun enough to have much of a positive developmental impact within the blind community. Provided below in Figure 4[20] are images of modern tactile-based toys available online. The top two toys are titled *Silver Abstractivity* (left) and *Green Abstractivity* (right) and the bottom toy's is *Textured Wall*.

[20] USA special needs toys - Tactile. (2018)

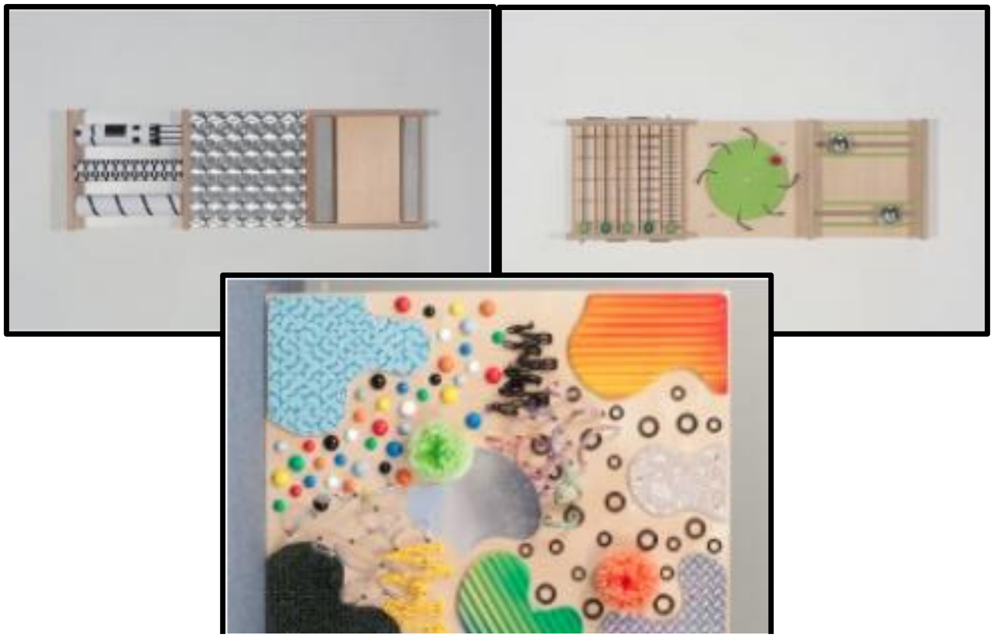

Figure 4 USA Special Needs Toys

Both of the Abstractivities are similarly designed, made primarily of wood, aluminum, holographic foil and a functioning periscope. Their main principal in gameplay is seemingly quick bursts of interaction whilst quelling fidgeting habits. These habits may involve auditory and tactile stimulation and in that respect all of these toys are very helpful and dynamic. However, in hindsight these toys are excellent examples of current problems afflicting the AT toy market today. While interesting in concept, all the toys are relatively simple in design consisting mostly of differently textured fabrics and tapes, rolling wooden dowels and a functioning periscope. The periscope is most likely the most complicated component among all of the toys, but even so these toys don't provide an engaging and stimulating experience for growing children.

It has been shown that play can be developmentally friendly for children, planting seeds for the growth of different social and sensory skills (fine/gross motor, auditory, linguistic, tactile, etc.) as well as self-esteem and a sense of responsibility[21]. Children develop social skills by learning to play with others and sharing, completing/winning a game can help instill a sense of

[21] How playing with toys can benefit your child's development. (2017)

accomplishment and confidence and the act of simply playing with toys can better/increase proficiency with fine motor skills. There are many ways in which toys/play can benefit children and visually impaired children are no different. In an article titled, “Play Deprivation in Children With Physical Disabilities: The Role of the Occupational Therapist in Preventing Secondary Disability” it states that “children with physical disabilities who are deprived of normal play opportunities are viewed as having a second disability that hinders their potential for independent behavior and performance”[22]. The article continues to state that a lack of free play amongst children with physical disabilities may begin to form physical, social, personal, and environmental barriers that may worsen if neglected. Caretakers and parents often want to protect their child, but limiting the activity, curiosity and freedom of children with a physical disabilities can lead to impediments in long term development and social integration. Due to the common assumption that a lack of senses leads to a lack of mental and physical competence, children with physical disabilities (in our case a visual disability) are underestimated and held back from participating in “normal” activities. All children require the freedom to explore and engage the world themselves and by participating in a variety of different activities of their own free will. This of course includes play. The chance to take risks arise from play and with that, the opportunity to master one’s physical self and accomplish something of their own free will[23]. Play is important to childhood development and neglecting the visually impaired population only further hinders their effort to integrate into society and live a fulfilling lifestyle.

Through the design of this toy, the hope is to help mitigate negative barriers preventing healthy development of visually impaired children in addition to an overarching primarily-fun focused experience. Creating a product that can fulfill such high expectations shouldn’t be

[22] Missiuna, C., & Pollock, N. (1991)
[23] Diamond, S. (1981)

underestimated, but that also doesn't mean the matter should be aside either. A quote that stood out from the words of Dr. Mary Reilly, once a professor of Occupational Therapy at the University of Southern California, stated that, "In an occupational behavior framework, play is considered to be the primary activity of the child, a prerequisite to competence in occupational roles later in life"[24]. After reading this, it only further cements the fact that this an issue that if neglected has both immediate and long-term detrimental effects on individual growth and development. Through this toy there is not only the opportunity to provide a vessel for a fun and developmentally friendly way to play, but also the opportunity to spread awareness of this issue and inspire other efforts to do the same.

3.2 Establishment of the Need

There exists a large gap in population size between visually abled and disabled children, after all, in 2015 visually disabled individuals only accounted for 2.3% of the United States' total population[25]. A possibility is that because the population size is so small, some may believe that their concerns are ultimately neglectable. This couldn't be further from the truth. As discussed in the previous section, play has an important role in individual development for children. Sheltering the children from *normal* activities can lead to long term developmental problems and underestimating their potential will only prove to be another hindrance in the long-term[26]. There exists the very prevalent matter of addressing the visually impaired population with this toy, however, one cannot simply ignore the fact that this community is very small and, with regards to product life, won't be able to produce enough revenue on their own to support this toy's business

[24] Reilly, M. (1974)
[25] Erickson & von Schrader (2016)
[26] Reilly, M. (1974)

model. However, this does not mean that the toy industry is dying. Looking at figure 5[27] it is clear that, while the total retail sale revenue made from toys has decreased in recent years, toys continue to play a large role in the market. In this information, arose a solution. Were the toy to abide by a universal design, there would be the benefit of broadening our market reach in addition to addressing the issues currently affecting the visually impaired population.

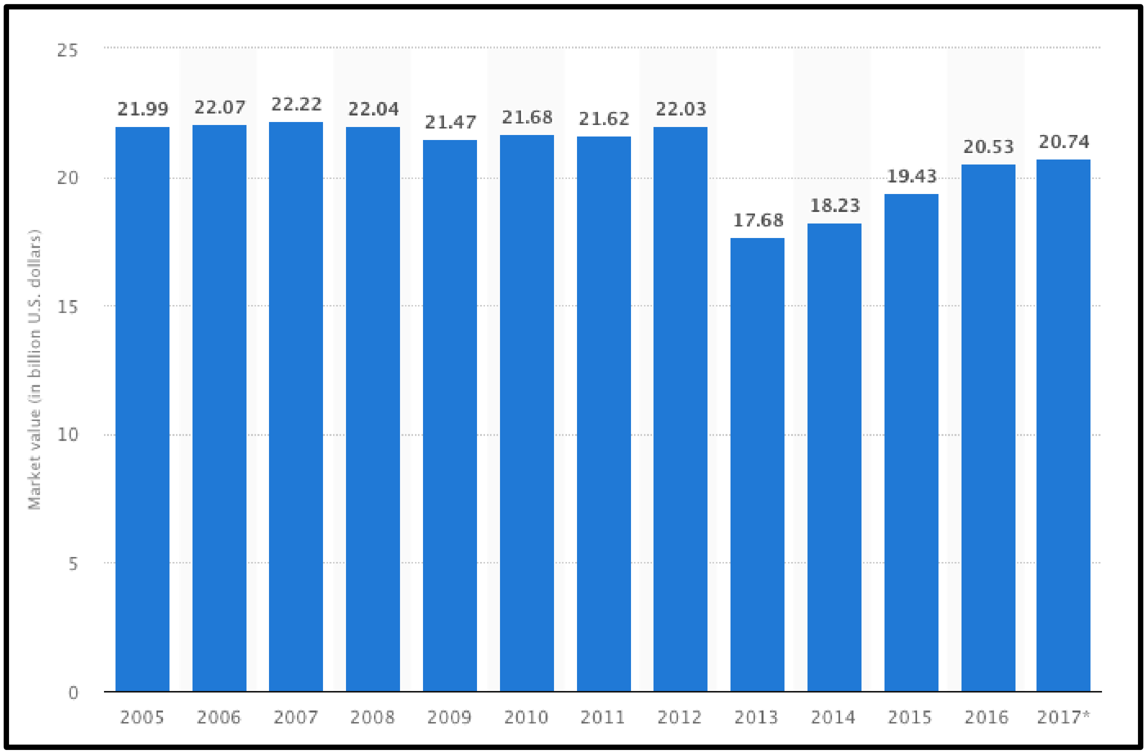

Figure 5 Toys retail sales revenue in the U.S. from 2005 to 2017 (in billion U.S. dollars)

Thus, there is a need to present a toy that offers versatile utility for visually disabled children while appealing to a larger and broader market to compensate for the small target population. Fortunately, this situation offers to kill two birds with one stone. By dedicating the design to a universal approach there is an opportunity to broaden the market reach for this product, but there also lies the opportunity to take advantage of the design to further bridge the social gap between the visually-abled and disabled populations. A universal design would signify that if the

[27] Market value of U.S. toys and games market 2005-2017 | statistic. (2018)

toy were created with appeal to both populations, the visually disabled may feel less targeted by the product. In the previous section, the topic of design arose and within it there was an analysis of the current AT toy market and the products available within it. It was found that more often than not, the toys available are under designed and serve more as tools than genuinely fun experiences and activities. Hopefully, by adopting a universal design the visually impaired will feel less targeted and as a result can help to integrate them better amongst society.

Moving forward, there is also the need to contact various organizations that relate to the intended demographic for the toy. The organizations include but are not limited to: The Easter Seals Non-Profit Organization, the Seven Hills Foundation, the Perkins School for the Blind, and the UMass Medical School (see figure 6). Fortunately, contacts were provided for UMass professionals through Doctor Cotnoir, and one team member had pre-existing relationships with both the Perkins School and the Seven Hills Foundation. The toy will continue to evolve so long as the appropriate effort is made in distinguishing what the visually-disabled do and don't need, thus, contacting these professionals will only further strengthen our product in the end. Connecting with Easter Seals first involved reaching out to their Worcester office. Fortunately, there came a time to establish contact through the grand opening of the Assistive Technology Regional Center (ATRC), an event hosted by the Easter Seals office. Doctor Cotnoir, was able to provide invitations to the event, allowing the opportunity to meet and network with professionals and lead users within the assistive technology field. This proved crucial in obtaining contact information, more footing on design concepts, and further knowledge of the current AT market. The first point of contact with the UMass Medical School was also established through Doctor Cotnoir. He was able to establish contact with John Rochford, a colleague, who is experienced in AT relating to blindness and visual impairments. John works as the director of the Shriver Center INDEX program at

UMass Medical and has designed text simplification software for those with cognitive disabilities. He was able to provide a large amount of insight and helpful information, considering that he himself had lost his eyesight at the age of sixteen and has lived with impaired sight ever since.

Figure 6 Perkins School for the Blind, Easter Seals Non-Profit Organization, UMass Medical School, and Seven Hills Foundation

Lastly, there will be a need to further examination of market segments and identification of other similar or identical products that are currently patented. While the development of the toy shouldn't be hindered in any way, every time the concept changes there's a risk that the resulting product will step into the territory of plagiarism or generic/repetitive concepts. Fortunately, Doctor Cotnoir's involvement in Becker College's Game Design program may also prove beneficial in conducting tests or showcases amongst game design students and staff in order to gain otherwise unobtainable perspectives and opinions.

In summary, there is a clear need to provide a toy that can assist in the development of visually impaired children. The toy must be able to achieve objectives such as provide a cheap and affordable base console for our toy, bridge the social divide between the visually abled and disabled and lastly, provide a fun-focused and engaging activity for all users. While this is much easier said than done, a quote that further resonated with the design objectives was from the Toy Industry Association that stated, "No less today than through the history of civilization, toys reflect the times and cultures and provide children with the tools that help them relate to the world in which they live. Today's toy manufacturers keep pace with the rapidly changing world and provide youngsters with correspondingly appropriate playthings for their enjoyment and to challenge their creativity and imagination"[28]. This cemented the belief that if able-bodied children are provided with an ever-growing and evolving selection of toys to test themselves and have fun, then disabled children should be provided the same resource as well. Disabled children possess the same capacity for fun than any other child does, by creating this toy the hope is that these children will be able to grow past any developmental impediments whether it be self-imposed or otherwise.

3.3 Preliminary Concept Development

We have investigated several potential solutions to the deficiency of developmental toys to assist visually impaired children. We developed certain preliminary concepts that vary between several different strategies. These solutions come from our development team and our analysis of the market through our literary and first-hand research, including focus groups and interviews with experts in the field as well as first hand analysis of current toys on store shelves. These preliminary design concepts revolve around certain criteria that was found to be vital for

[28] Market value of U.S. toys and games market 2005-2017 | statistic. (2018)

our product to succeed. Universal design is one of these crucial parameters. It is important that the product in development is accessible to our target audience, visually impaired youth, but also that the product is worthwhile to those outside of our target audience. We will design the product in such a way that children suffering from a visual disability can play with our product at the same level as a visually capable child. By approaching our design this way, we will begin to break down the recreational barrier between disabled and non-disabled individuals. We want these groups to be able to play with the same toy without feeling that it is designed for one or the other. This also allows access to a broader toy market. Our goal is to make the reach of our product as wide and diverse as possible. The product will also need to be simple and have a high replay value. During the market research phase, we came across relevant products that were already on the market. After analyzing them, we were able to identify successful and unsuccessful design elements that went on to influence our potential solutions.

One of the constraints we had to work around was the ability of our target audience. We had to concern ourselves with the limited ability of a child in our target age range. Our designs must be tailored to the abilities of a child including their range of motion, mastery of fine motor skills, critical thinking skills, and decision making. To ensure that our toy is accessible to children, we will regularly play test our prototypes throughout the development process.

In addition to the development of a child's body and brain, we must also consider the limitations of a visually impaired person. When considering the implications of a visual disability, we have assumed that those with a visual impairment have the same cognitive ability as another child of the same age. In designing this product to optimize universality, we have chosen to assume that the impaired children are severely blind. If a child who is severely blind can operate and enjoy the toy, then a child who suffers from partial blindness will (theoretically) also be able to, with satisfaction.

3.4 Focus Group Clinics

When attempting to define the toys' concept, there are a variety of systemic tools at our disposal that can be used to the team's benefit. One such procedure is focus group interviews/clinics. The objective of a focus group clinic is to spark conversation and observe interactions between the focus group participants[29] while also trying to guide conversational topics in a manner that contributes to overall concept refinement. These are rare opportunities to obtain priceless raw input and feedback concerning our toys' aesthetic, gameplay, mechanics and appeal. Accomplishing this in a natural, comfortable and constructive space will only further contribute to the thoughtful conversations already being had. "Group discussion is particularly appropriate when the interviewer has a series of open ended questions and wishes to encourage research participants to explore the issues of importance to them, in their own vocabulary, generating their own questions and pursuing their own priorities."[30] By following this general guideline we were able to condense the appropriate information into concepts that were properly applicable in our design and perhaps some that were not so efficient to our final design.

Furthermore, it is important to take into consideration some general knowledge that should be incorporated in our ultimate focus group outline. The first note being that Focus groups are used as effective means of identifying cross cultural variables, which are defined as varying cultural factors presented as common knowledge that are either present in one or more different cultures.

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[29] (Kitzinger, 1995)
[30] (Kitzinger, 1995)

A key to conducting an effective focus group clinic is focusing on homogeneous traits/characteristics, this way we can capitalize on what brings the participants together versus what makes them different.

Intro (Setting the stage)	Body	Closing
- Introduce yourself - Purpose of the day - How the day will be run - Have participants sign consent form	- Ask questions (See question development)	- Let people know once again how helpful they've been - Make them aware of how they can reach you if they have any questions or additional thoughts

Figure 7 Conducting a focus group; how to get started

The following objective would be to outline the structure and schedule behind the actual focus group clinics. As the facilitators, there lies a natural inclination to engage and interact with the participants, but like previously stated, the 1st half of the clinic should revolve around "structured eavesdropping", which is the facilitation of a dynamic/structure to a group and taking notes while not directly participating as much as the participants are. During the later half, the facilitators have the opportunity to take much more direct action. Hopefully, by the later half of the clinic the participants will be comfortable enough to answer more direct questions that serve as key questions to the facilitators and the designers of our prototype/product[31].

With all this information taken into consideration, it can be condensed into a general structure and outline for the script leading into focus group clinics. With the provided graphic

[31] (Kitzinger, 1995)

presented in figure 7, it’s clear to see that the structure exists and all that is left to do is tailor it to the product design objectives. With this information in mind and the willingness of the participants, the information needed to completely refine our design will be found.

3.5 Decomposing the Design into Sub-Problems

After narrowing the potential solutions and choosing a design concept to pursue, it became evident that the design of the Show & Tell can be decomposed into several sub-problems and design components. We were able to identify and act on each aspect of the design. In the following sections, the design is discussed in terms of these sub-problems.

3.6 Creating a Prototype

In the development of our concepts we came to a point where we needed to test our ideas. We developed two prototypes of different nature to test certain aspects of our design. The first prototype was initially to test our game flow and understand how playing with our toy would feel. To do this a paper prototype was manufactured using basic materials, namely cardboard and construction paper. The target audience for use with this prototype was only sighted individuals due to the simplicity of the features. The goal was to have a prototype which simulated the function (not performance) of each component involved in the game play of our toy. This included representing the tiles, tactile artifacts (in this case we used dinosaur figurines), the keying mechanism for the ties, the buttons, and the scripted audio for the questions, dinosaur facts, successful and unsuccessful responses.

For this prototype, first, a cardboard box was cut to the dimensions of our base unit SolidWorks model: 22.5 cm x 33 cm x 7.5 cm. Using a ruler to draw a rectangle that was 22.5

cm x 33 cm with one corner in the corner of the cardboard box. By doing this, two of the four walls of the base unit are used coincide with two of the walls of the box. Doing this meant that only two cuts were necessary for the first step rather than one cut for each of the four sides. It also mitigates the number of side panels that would need to be added after cutting the top face. Next in producing the base unit for the prototype we looked at our design from the front and side views to see the dimensions of the side panels; 22.5 cm x 7.5 cm and 33 cm x 7.5 cm for each side and front/back faces respectively. Using these dimensions, two rectangles were cut from the scrap of the box, one side face and the back face (since one side face and the front face were already attached from step one). We attached these two walls with a hot glue gun and holding the pieces in place as the glue settled. In this prototype there is no simulation of the power button, speakers, or USB slot so after cutting the box to be the dimensions as the SolidWorks model of our design, we covered the prototype base unit in blue construction paper, representative of the color scheme.

The toy design includes incorporating Play Packs with five Tiles in each. There are two major aspects of the tiles being tested with this prototype: the game mechanic of picking up tiles to exploring them with touch, and the keying mechanism. These tiles have artifacts that incorporate textures to help the user identify key features. To simulate that, we purchased a pack of dinosaur figurines from the local dollar store. These have figurines were chosen based on unique physical characteristics such as horns or spikes. In gameplay the player is asked to select the dinosaur that is being described (e.g. "Which dinosaur has 3-horns on its head?") by picking up the tiles and investigate them and the pressing the tile button associated with the correct tile. The base unit must know what location the tile is in to know if the player has selected the appropriate tile. After many brainstorming sessions, a keying mechanism was designed such that the tiles could only fit into one position while still feeling uniform and symmetrical. The tiles are all based on an equilateral hexagon, but they are unique in that they each have two triangles cut out of the them. Once discovering all the unique representations of a hexagon modified by two triangular cuts, the geometry of the keying mechanism was chosen based on symmetry and aesthetics. With this mechanism the unique shape of the tile slides into a uniquely shaped hole. Although visually there is a sense of symmetry it is important to realize that by considering this mechanism with limited to no visual input.

In this prototype we took the scale drawing of the parts in SolidWorks and printed them on paper. Then we cut the tiles drawings out and used them as stencils to cut out tiles from cardboard and construction paper. A tile paper tile shape was glued to the top of the box to represent the specifically shape hole for each tile to slide into position. Once each cardboard tile was colored orange, a tactile artifact was added to each; in this case five dinosaur figurines were placed on the five tiles. Dinosaur toys were chosen and purchased based on physical features recognizable by touch. The Five dinosaurs used are the Stegosaurus, Triceratops, Pachycephalosaurs, Ankylosaurs and the Dimetrodon. These dinosaurs have features like spikes on its shell and tail, or a large fin on its back, which can be sensed by picking up the tile and exploring it with touch.

In this prototype the buttons are represented but are not functioning. Mostly, the goal was to show button placement to determine how the user would move and flow around the device while playing and pressing buttons. Six buttons were cut using the same method of printing out the drawing to scale of each button and cutting cardboard and construction paper using this drawing file. This ensured that the buttons were proportionally consistent with the tiles. The purpose of having nonfunctioning buttons was to be able to analyze the movement patterns of the player as they play a certain game mode and move between buttons and tiles.

For the sake of this prototype, a single game mode was developed around a single play pack. In this game mode a prompt would ask the player to select a specific dinosaur (e.g. "Which dinosaur has 3-horns on its head?"). The selection of the dinosaur is done by pressing the button closest to that tile. Through this we were able to test game development concepts and iterate on our game design quickly and effectively. The full script of our game mode can be found in the appendix.

The second prototype has constructed of wood, 3D printed parts, and electrical components. The body and button tray were laser cut from ½-inch and 7/32-inch plywood using a VLS-4.60 a 60-watt CO2 laser. The Buttons and Tiles were 3D printed using a Form 2 SLA printer and the PreForm slicing software to prepare SolidWorks models for print. Several electrical components (tactile buttons, volume controller, power switch, etc.) were purchased online. This prototype was more complicated and was able to be developed once further development occurred in the mechanical design as well as the game design.

In order to laser cut the pieces to manufacture our beta prototype, new part files needed to be created in AutoCAD. This is because the laser cutter used required uses software which reads two dimensional .DWG files open in AutoCAD. To do this the model of the base unit was broken down into six panels, top, bottom, left, right, front, and back. The left and right panels contained the speaker grills, and the front panel had the USB slot. The top panel had to include all of the cuts for the five hexagonal Tiles, the 5 trapezoidal buttons and the central button. The bottom panel has no cuts. The button tray was also laser cut on this machine. The button tray holds the components for the 3D printed buttons as well as the vibrating motors for the Tiles.

In order to 3D print a part modeled in SolidWorks, we first had to create .STL files of each part and then open the .STL files on a slicing software. This process effectively takes a solid model and converts it to a series of points that the slicing software then interprets and transforms into a series of layers based on the layer thickness and infill set for the machine. Components of the design which were to be 3D printed were the five hexagonal Tiles, the 5 trapezoidal buttons and the central button as well as the rail system designed to improve the path of the buttons. Given the print bed size and other restrictions of the machine, five prints were planned, totaling nearly 45 hours of print time. This time estimate was taken based on the PreForm slicing software which considers material properties, print resolution, and the specific machine being used. A spreadsheet was made to track the estimated time of printing which can be seen below in figure 8. After each print, the parts must be cured in UV light and support material must be removed.

Table 1 3D Printing Time Estimates

	Print Name	**Hours**	**: Minutes**	
1	1 Tile Buttons	3	50	**Total**
2	4 Tile Buttons	9	5	**44.167 Hours**
3	2 Tiles	12	55	
4	3 Tiles	15	59	
5	Tile Caps A-E	2	21	

Several electrical components needed to be purchased online to complete the prototype. Each 3D printed button needed to have an electronic button to be able to register the press of a button as a digital input. Six total 6mm x 6mm buttons and six 0.25-inch-long springs were used, one for each of the buttons in the design. A potentiometer with a spin wheel was utilized for volume control as well. A power switch with an LED and a tactile difference between on and off was incorporated as well.

3.7 Leaving the Solution Neutral Space

For our development team, existing in a ‘solution neutral space’ meant a couple things:

1. It meant that we sought to create a toy for blind children that was fun and engaging. Conventional toys simply don’t exist for the visually impaired, and we wanted to change that because every child deserves to have fun, and to engage in play.
2. Our toy had to be helpful. We had the opportunity to make a difference— a responsibility not to be taken lightly. Whether ‘helpfulness’ came in the form of incorporating an educational element, or by being a toy that was able to facilitate social/emotional development, were details that existed *outside* of the scope of being solution neutral.
3. The toy had to be universal. If we developed a toy that wasn’t playable or fun for children who *weren’t* blind, then the design would be a failure since it wouldn’t be a strong competitor in the market. Further, a toy that’s designed to be fun for everyone is more fun than one that isn’t.

Using these guidelines, we placed no other initial limitations on the form or function of our design. After defining what it meant to be fun and learning exactly what children found most desirable in best-selling toys, our team was to ready to give direction to the product’s concept development and leave the solution neutral space. To do so, we attended events and interviewed professionals who worked with assistive technology. As authorities in their field, our hope was to receive key insights that we could use to give focus to our concept development.

3.8 Interview with John Rochford

After attending the grand opening of Easter Seals' Assistive Technology Resource Center (ATRC) in Worcester, our team left eager to develop an innovative addition to the AT available for the blind. We were able to network with professionals of diverse roles in the space of assistive technology and establish interest in our project. Many of these professionals went on to participate in our focus clinics.

We later made arrangements to interview John Rochford— a visually impaired man who has worked extensively with assistive technology in his time as director of the UMass Medical Shriver Center's INDEX program. As a person who not only lives with blindness but has also designed items for those with disabilities, Rochford's insights were particularly valuable to us. Rochford's unique background as a member of the blind community juxtaposed him perfectly to give us insights that we could use to give direction to our development.

Throughout our interview with Mr. Rochford, he underscored the need for *something* that could help the blind with their wayfinding abilities. Though only 10% of the blind have absolutely no vision, blind people are typically dependent on memorization for navigating their own homes and find themselves completely dependent on others when navigating larger spaces like airports. Beyond those anecdotal examples, it's simply a fact of life that navigating from place to place safely and reliably is a necessity in today's society. Rochford argued that blind children would benefit from a toy that gamified wayfinding without sight and went on to suggest that our team should focus on developing such a solution.

Receptive to his case, we decided to pursue development of a toy for visually impaired children whose premise revolved around wayfinding. Wayfinding is not only an indispensable necessity, but it's also one that lends itself quite well to toy design. With that, we had officially left our state of solution neutrality. Now we were focused on creating a toy that was able to improve a player's way finding abilities when they were unable to depend on their sight.

Our team immediately went to work and began brainstorming a range of toys that incorporated a wayfinding element. After we had ideated applications of wayfinding in typical toy categories (like board games, active games, and competitive games), we developed a weighted decision matrix that allowed us to quantitatively determine which concepts accomplished our goals the best. and go through another round of discussion now that we had ranked each design and its elements.

3.9 Detail Design

The Final detail design of the innovative product was created using SolidWorks Computer-Aided Design software. This is a 3D solid modeling computer-aided design and computer-aided engineering software which allowed us to design and analyze our design effectively. Using SolidWorks, we were able to create 3 dimensional models as well as 2 dimensional drawings. We were able to model each component present in the final product in the SolidWorks model, including the springs and tactile buttons and the material properties associated with each component. A discussion of the final design can be found in the results section of this report: Chapter 4.4 Detail Design.

3.10 Evaluate the capacity

During the concept development stage of our product design process, while leaving the solution neutral space, several unique products were designed and iterated on. During the development of our innovative product, it was necessary to evaluate these potential solutions and determine which was best fit to solve the problems identified in the current market. The most notable design in comparison to the Show & Tell is the development of a seeing-eye companion robot as a wayfinding toy for use in and out of game play. This concept was most notable because it progressed furthest in development as a viable solution to the problem identified in this report. Though this was a viable solution to a lack of wayfinding technology for visually disabled youth, however this product began to develop into a primarily assistive tool rather than a primarily fun toy. The companion robot acted as a tool to help the visually impaired community to more safely and independently navigate in and around building to defined points of interest. Game modes were developed to play with the companion robot on a small mat which also acted as a training ground for the use of the device outside of game play. Albeit a fun toy with engaging and educational/developmental games, this product was primarily an assistive technology device, and this does not effectively satisfy the goal of developing a toy that is primarily fun with no ulterior motive. Because of this, we chose to develop another toy design, and thus developed the Show & Tell by primarily focusing on the development of a fun game and then creating a product to play that game. This was different from the wayfinding toy in that the wayfinding toy was developed by first creating a fun and engaging device and then creating gameplay for the device. Doing this led to a much more effective design as it better accomplished the objectives and goals of this project. Through the evaluation of our product ideas, the Show & Tell was determined to be the most capable solution.

3.11 Determine product cost

The construction of the alpha prototype was low cost both in terms of materials and time as it was comprised of only paper, cardboard and plastic dinosaur figurines. However, the production of the beta prototype required the purchase of certain materials and components. The Table 1 below shows the costs of the components for this prototype.

Table 2 Bill of Materials for Prototype Construction

Item Name	Supplier	Price (USD)	Quantity per price	Quantity Used	Cost of Material Used
Tact Button Switch 6x6x5mm Pack of 100	Amazon	$6.80	100	6	$0.41
5Pcs 16mmx2mm 10K ohm Stereo Volume Control Wheel Potentiometer	Amazon	$5.45	5	1	$1.09
DC3V/0.1A 1.5V/0.05A 10x2.7mm Coin Mobile Phone Vibration Motor	Amazon	$9.88	10	5	$4.94
1/2" x 2' x 4' Birch Plywood	Home Depot	$21.97	8	3	$8.24
Sanded Plywood (5.2 mm x 2 ft. x 4 ft.)	Home Depot	$10.96	8	2	$2.74
Compression Spring, 302 Stainless Steel, Inch, 0.24" OD, 0.022" Wire Size, 0.127" Compressed Length, 0.25" Free Length, 1.99 lbs Load Capacity, 16.24 lbs/in Spring Rate (Pack of 10)	Amazon	$8.08	10	6	$4.85
Adafruit Wave Shield for Arduino Kit	Amazon	$23.80	1	2	$23.80
Arduino Uno R3 Microcontroller	Amazon	$19.99	1	1	$19.99
Speaker - 0.5W (8 Ohm)	Sparkfun	$1.95	1	2	$3.90
				Subtotal	$69.95
Massachusetts sales tax				6.25%	$4.37
				Total	$74.33

Chapter 4: Results

4.1 Need Statement

From our initial concept development, we had set out to create a toy that had the potential of immersing visually-impaired children more in the world around them. Without an effective sense of sight, it's nearly impossible to distinguish physical features without literally feeling the object or being in front of you. Though limited in reach, the sense of touch is still widely present across both the visually-impaired and abled populations of children. From our focus group session at Becker College, a majority of the participants agreed that their tactile senses played an important role in their infatuation with a particular toy from their childhood[32]. Using this information, we decided to attempt to enhance the effects of tactile stimulation in our design. A focus on tactile stimulation as a means of gameplay not only appeals to young children everywhere, but it may also offer a type of sensory input more descriptive to blind children than anything they have been able to play with before. For the blind, touch is widely used as a tool for understanding what exactly lies in the world around them. By offering this platform as a vessel for individual growth and understanding, we are attempting to extend the reach of understanding about this world for blind children.

As children mature, they begin to understand more and more about the world around them. Through better understanding of their respective environments, children are more capable and efficient in communicating their ideas. Thus, a lack of understanding of one's environment can theoretically lead to a poor development of communication and social skill. Considering this, we gave focus group participants the opportunity to discuss the potential for social development

[32] Potential Google Form question

present within toys. A majority agreed that a common interest in a particular series of toy or media as children effectively led to an easier time relating with fellow children and classmates[33]. Even when it came to relationships developed later in life, the reactions we received during our focus group sessions lead us to believe that the ability to relate to others through something as simple as a toy can assist in long term social growth. This reinforced our belief that by giving blind youth the means to understand and relate to the world around them, they gain the additional benefit of being able to better relate with other members of society. As a result, we believe that we have created a design possessing a universal interface effectively providing those means.

In addition to an emphasis on design quality, we had to be mindful of fun and its very relative definition. Fun is virtually immeasurable and varies in preference from individual to individual. So, the question arose, “what made toys fun”? We were able to ask the focus group participants the same question. An emerging theme we noticed among the participant’s experiences was that competitive gameplay mechanics present within their favorite toys worked as catalysts toward further enjoyment of that toy[34]. This was especially noticeable in those that preferred toys such as video games and board games. In our discussion with the focus group participants, it was also noted that the act of playing with toys was fun because it was a distraction from what would be considered work to a child[35]. Playing with toys didn’t involve completing tasks similar to that of homework assignments, instead it focused on gameplay designed to inspire imagination and creativity in their own respective definitions of fun. Using this information, we can rationalize that by offering gameplay personalization through open source methods we are able to create a platform customizable to any individual’s definition of fun.

[33] Potential Google Form question
[34] Potential Becker question
[35] Potential Becker question

It was noted previously that an appeal for toys was that they were relatable between different individuals and that is in part due to product availability. An open source method of approach would allow for immediate availability among all platforms and would essentially provide unlimited continuity in gameplay whilst relying on collaboration within the user community. In reference to past themes, this may also improve social growth, the toy's capacity for fun and the immersion of the visually-impaired in their respective environments. Through surveying, we were able to notice a positive reaction regarding our use of open source methods within our design amongst the participants[36]. Many of them expressed their pleasure concerning the approach. This worked to further fortify our approach in design and conceptualization.

4.2 Establishment of the Need

According to the research we discussed in the background section of this report, we felt it necessary to present our market segmentation process. Comparatively, blind children account for a much smaller portion of active students in the nation compared to the much larger population of abled children. The difference in the audience size felt too large to ignore. In 2015, individuals living with disabilities only accounted for 12.6% of the total population and of that percentage only 2.3% reported them as a visual disability[37]. In order to attract a broader demographic of users, the design was directed to also be appealing to non-visually-impaired children as well. After discussing this topic with the participants of our focus group at Becker College, most were in accordance with our reasoning[38]. By pursuing both populations we are extending the reach of the toy, as well as limiting risk of our toy being seen more as an AT device rather than a toy. However,

[36] Potential Google Form question
[37](Erickson & von Schrader, 2016)
[38] Potential Google Form question

we mainly felt the need to address our interest in both populations due to the nature of our philosophy. We sought to create a toy that could ultimately bridge the social gap between the visually impaired and the world around them.

Similarly, we also discussed the process in identifying potential lead users for our toy. Significant effort went into identifying an appropriate operating age range for the toy, so we decided to ask students and professionals what specific age range they could perceive the toy being used by. According to our survey results, a majority of the participants would expect this toy to be used by children between the ages of 6 and 12[39]. This confirms the validity of our imposed operator age range that was previously under speculation.

During our initial research we also sought to find information that could help distinguish our toy amongst the rest of competition on the market. We were able to find such information by identifying top selling, developmentally friendly toys currently being sold and analyzing their design characteristics and potential. In our research we found that a large portion of the toys were simplistic in design and didn't offer much in terms of variety in gameplay, specifically in reference to toys such as the Little Tikes Light n Go 3-in-1 Sports Zone and the Hape Pound & Tap Bench[40]. With this in mind, we believe that we've provided the base for a platform that has the potential for extensive options of play with a design whose appeal is derived from the ability to customize gameplay to any individual's preference.

Additionally, in the process of identifying similar products in the market we were also able to identify other patented products that seem similar in design to ours such as the Early Childhood Learning Toy[41] and the simulator toy for the development of fine motor skills, tactile and

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[39] Potential Google Form question
[40](Vercelletto, 2017)
[41](Manalo; Teresita D, 1994)

coordination of hand movements[42]. At first, there was concern as to how we would differentiate our toy technically and whether there was enough variation in gameplay from the next closest product. However, by using the information provided in these patents as a guideline, we were able to steer the design of our toy in a direction completely different from that of existing products. As a result, we believe that we were able to create a design that can truly be considered unique in aesthetic and functionality.

During our initial statistical research involving the target demographics, we were able to establish that in general a large portion of individuals living with a visual disability currently live below the national poverty line. To be specific, that is 29% of individuals, between the ages of 21 and 64, living with a visual disability that live below the poverty line[43]. By taking this into consideration, we were heavily incentivized to pursue a cost-efficient means of production when it came to physically creating our design. Our alpha prototype was made entirely of paper and our beta iteration was mostly comprised of materials such as wood, 3D printed plastic and paint. We'd estimate that on a mass production scale, injection molding would only further mitigate production inefficiencies thus contributing to the overall end quality and price of our toy[44].

4.3 Concept Development

The third phase in product design is Concept Development. In this phase of product development, the goal is to (1) determine the design's feasibility, (2) decompose the design into sub-problems, and (3) create a prototype.

[42] Г.Р. Ковбай, (2002)
[43] Statistical facts about blindness in the united states (2017)
[44] Potential Survey Question

4.3.1 Feasibility

We determined our design to be one that was conceptually viable in today's market because no other product addresses the problems that we identified, and it has the ability to change lives and connect people who were previously disconnected from one another. When asked, we found that 100% of focus group participants strongly agreed with the statement: "The Show & Tell is a unique concept that I believe people need."[45]

Concluding that we had developed a feasible design was also influenced by the surrounding economics of both the toy and assistive technology industries. By the market feasibility of the Show & Tell in our research and analysis of assistive technology, starting with what was available at the MassMATCH Assistive Technology Resource Center in Worcester.

After examining popular toys and assistive options in the space, it seems that current toys for the blind have failed to take consider the fact that the visually impaired are capable handling tasks of any complexity and can instead interpret information we might otherwise communicate visually *using their other senses*. Typically, toys for the blind are synonymous with toys for toddlers-- which is not only insulting, but also squanders an immense opportunity that exists in giving the gifts of play and a more intimate connection to the outside world to a child that otherwise might not ever be able to experience either. It was the identification of this hole in the marketplace that led us to believe that our design's concept was one that made sense to act on. Our concept is

[45]See Appendix H: Focus Group Results

original, new, and something that people need. In the market of toys for blind children, we found that there are no options that have used modern design principles and technologies when acting on the needs of this demographic. Between AT products that are poorly disguised as toys, and textured polygons passing as toys, there is an ocean of products that have not evolved and have not taken properly considered what their target demographic really needs.

We decided early on that it was the idea of our toy's mission that was powerful, so the toy should act as the vessel for that idea-- the design should be universal and modular such that it is flexible enough to take advantage of the ability to have an infinite variety of Play Packs. We also decided that we wanted our toy to be accessible to the people who need them, because they're otherwise being exploited by the irresponsible pricing practices of the toys that already exist in the space. These conclusions led us to create a design that was simple, symmetrical, and had a low manufacturing and production cost, along with considerations to make as much of the content open source as possible. Of our $1,000 budget, building a prototype cost us $74.33. And with that, we were left with a significant number of extra parts[46]. Our design is also modular, and has infinite capacity for expansion. Also, when taking into consideration our goal to provide open source content, this means that other people could conceivably do the same if provided with instructions. After asking focus group members how they felt about our pricing on a scale of very unreasonable to very reasonable, 42.9% responded that they believed our prices were "reasonable," and the remaining 57.1% found our pricing structure to be very reasonable.3 Additionally, since anyone with a 3D Printer (which can be purchased for less than $200 on Amazon, with the 'Amazon's Choice' 3D printer – the Flash Forge Finder – selling for $400[47] in April of 2018) is capable of

[46] See Appendix D: Bill of Materials and Parts Spreadsheets
[47] https://www.amazon.com/FlashForge-3D-Printers-New-Model/dp/B016R9E7J2/ref=zg_bs_6066127011_8?_encoding=UTF8&psc=1&refRID=2HQRTXJF2VYRMA9539DA

instantly downloading Play Packs and games, and then printing the Tiles. Because of this, the cost to the user can drop significantly. In addition to that cost, consumers would only have to pay what we charge them for a digital download of their Play Pack's 3D STL files (for printing Tiles), and whatever files they needed to run the game that accompanied the Play Pack they had bought. In that process, the only cost that we incur is the time to create and host a single version of the files. Having the ability to do this, along with the limitless nature of our Play Packs, removes the typical boundaries surrounding replay value and opens completely new possibilities for sales.

In addition to the economic forces surrounding the blind, the toy industry commands incredible buying power[48]. The blind are also a sizable population, and though not as much, also command notable buying power[49]. When considering where our design might be sold or distributed, we believe the best course of action would be to partner with an organization like Perkins School for the Blind that can use the toy in their classrooms, take advantage of bulk purchases, and get the toy directly into the hands of children who could use it and use it socially. Because of this, we approached the design of the Show & Tell toy with the intention that it would be integrated into classroom settings, but it could also certainly occupy shelf space in stores like Walmart, Target, and Amazon. These three retailers are not only the best-sellers of toys in our country, but after deciding to close down all of its stores, Toys "R" Us publicly stated that they blamed Walmart, Target, and Amazon for their bankruptcy[50]. Though this may not be the best news for a retailer that exclusively sells toys, the market cap for toys does increase every year. This tells us that if we are able to compete with toys that occupy shelf space at these stores (or in Amazon's case, those that are best selling), then we have the ability to take full advantage of the

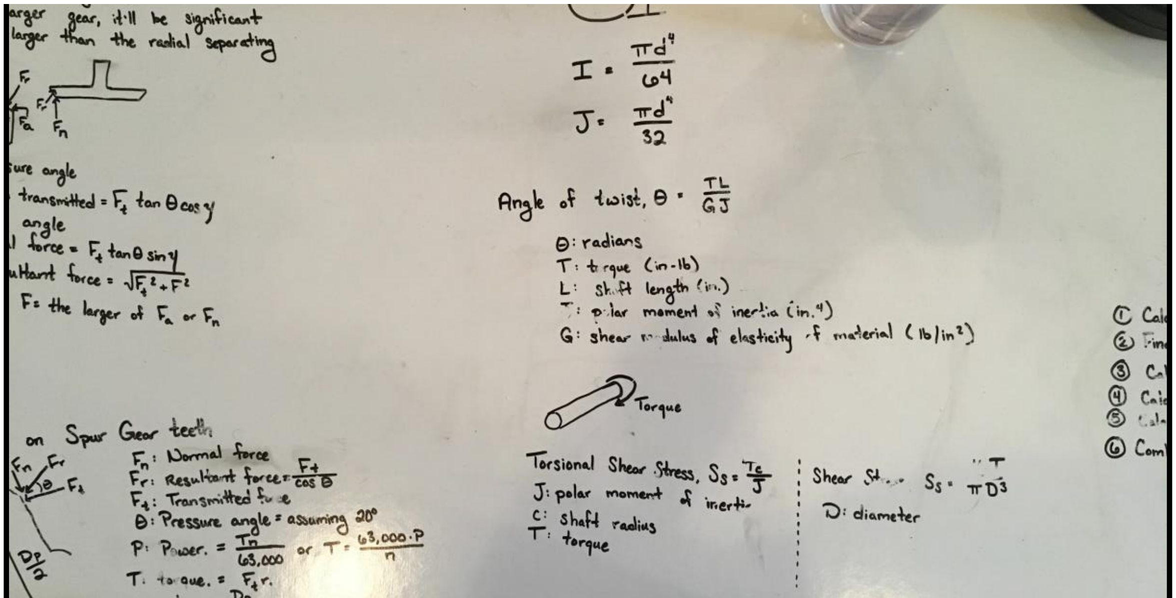
[48] See Background: Chapter 2.2: Market Reach
[49] See Background: Chapter 2.2: Market Reach
[50] https://www.usatoday.com/story/money/2018/03/15/toys-r-us-liquidation-amazon-target-walmart/427209002/

economics surrounding the greater toy industry. Accomplishing this would amplify our ability to act on our mission, and additional demand would also drive prices production down. The result of gathering all of this information is that we were able to more precisely set boundaries, scope, and philosophies of our design decisions.

4.3.2 Decomposing the Design into Sub-Problems

When approaching the design of the Show & Tell, the creation of each design element was the result of finding the ideal solutions to the problems surrounding it. We were able to arrive at fundamental thoughts that must be taken into consideration for every single aspect of our design that the user interacts with. We would use any revelations gained from this process in our regular breakout brainstorming sessions.[51]

[51] See Appendix B: Whiteboard Pictures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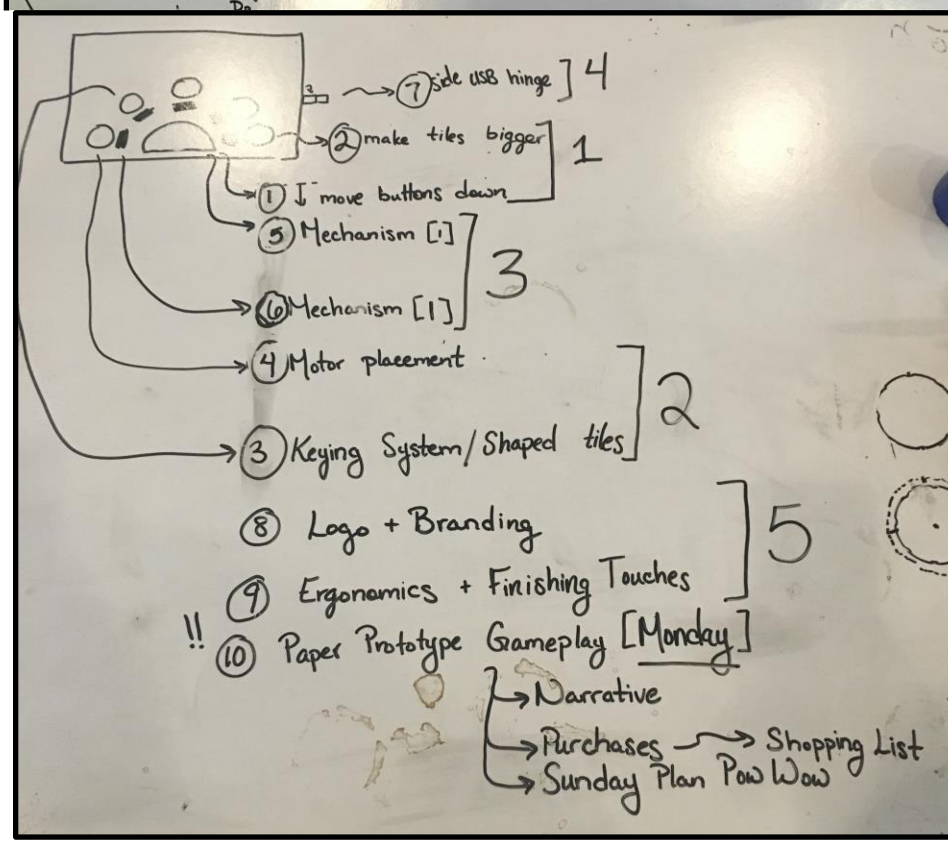
Angle of twist, θ = TL/GJ
θ: radians
T: torque (in-lb)
L: shaft length (in.)
G: shear modulus of elasticity of material (lb/in²)
Torque
on Spur Gear teeth
Fn: Normal force
Fr: Resultant force
Ft: Transmitted force
θ: Pressure angle = assuming 20°
Torsional Shear Stress
J: polar moment of inertia
c: shaft radius
T: torque
D: diameter


7 side USB hinge] 4
2 make tiles bigger
1 move buttons down] 1
5 Mechanism [1]
6 Mechanism [1]] 3
4 Motor placement
3 Keying System/Shaped tiles] 2
8 Logo + Branding
9 Ergonomics + Finishing Touches] 5
!! 10 Paper Prototype Gameplay [Monday]
Narrative
Purchases → Shopping List
Sunday Plan Pow Wow

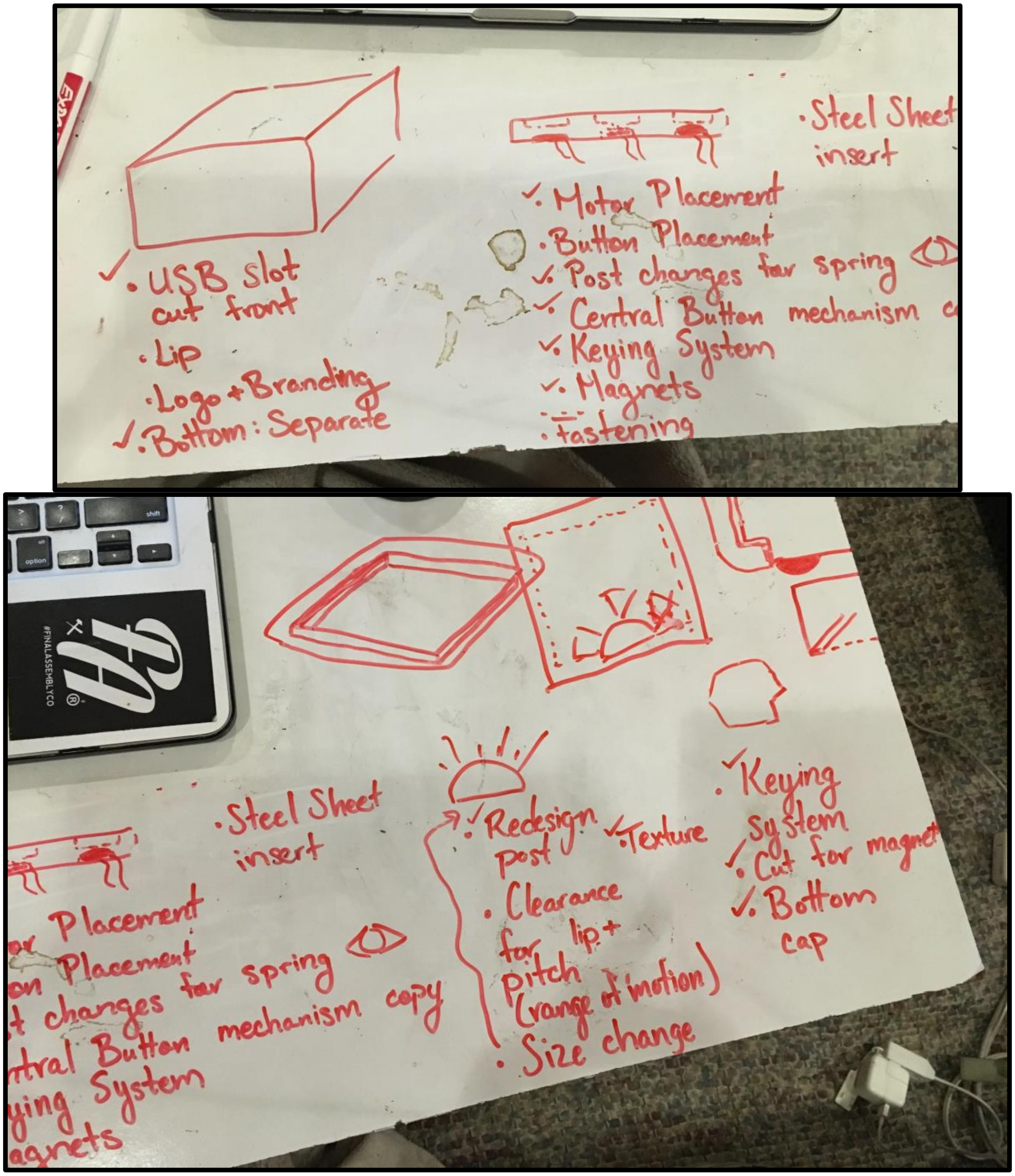


Figure 8 Pictures from brainstorm sessions taken from our design board.

4.3.2.1 We Are Biased as Sighted People

This was the first idea that we realized was a central design focus, and the most important one. As designers, we are designing a product *using our eyes* for those that cannot rely upon theirs in the same way that we can. Because of that, their views on what reality should 'look' like are not at all based on our definitions, which come from information we perceive through our eyes -- where 80% of what we believe to be the world around us, as sighted people, is based on what we see (Hill & Blasch, 1980)[52]. Though it is again worth noting that only 10% of people are totally blind[53], this idea lead to a realization: With design intent, we could design the user interface with texture cues and user experience at the forefront. In that, we are able to make our toy a space where players must use the Umwelt available to them (their amount of sight, and whatever discernable sensory stimuli we can provide them with; additional dimensions with which they can interpret the space of the game) to interact with the game and its pieces. We realized that we have to be consciously aware of the face that we are designing things based on the information we are receiving from our eyes in **all design decisions.** The implications of this for our design was, the significance behind constructs like symmetry, golden ratios, and what is ‘appealing’ is called into question. But even so, in being able to connect the blind to a world where constructs like symmetry and relative proportion have meaning in their interacting with the toy is another key aspect of its design. And though they may not be able to see that by looking at the box and understanding its design visually, they can feel every piece of it, and that is arguably a more intimate way to come to know anything. For this reason, symmetry, use of polygons, and use of geometrical ratios like the golden ratio and Fibonacci sequence were used in many places throughout CAD sketches as our basis for proportion. These constructs have significant meaning in how we interpret our visual reality, and so a person with limited sight using a toy that is designed to help them connect to the

[52] Hill, E. W., & Blasch, B. B. (1980). Concept development. In R. L. Welsh and B. B. Blasch (Eds.), Foundations of orientation & mobility (pp. 265–290). New York: American Foundation for the Blind Press. Retrieved from http://www.cde.ca.gov/sp/se/sr/documents/braillereadstand.pdf

[53] See Appendix A: Interview with John Rochford

outside world should take into consideration the fact that proportions are involved in every single thing we see and interact with.

4.3.2.2 This Toy Should Prioritize Fun to Utility

Our original impetus was to design a toy that was fun for the sake of being fun[54]. This took a backseat when we decided to pursue a design that had utility; that is, one that also actively functioned as a piece of assistive technology to some degree. Eventually settling on wayfinding, we realized that as engineers, we have a responsibility to make a positive impact on the people who are affected by our product. After reconsidering what our original goals had been and the developmental benefits that come with a positive play experience[55], we decided to refocus our efforts on designing a toy that placed fun at the forefront and didn't focus on trying to 'fix' the user's blindness, like we might have with our past wayfinding concepts. Additionally, in order to ensure that production of our design can have the lowest possible cost, it became important that the toy was also fun a sighted person. 77% of focus group participants who played with their eyes open said that "They had a fun time and would be willing to play another Play Pack in that sitting."[56] This meant that our design was universal in its appeal -- both sighted and visually impaired people could have a good time playing with our toy. This meant that the Show & Tell could also feasibly occupy shelf space in stores and participate in the grander toy industry. Also, in creating a toy that can be played by both the sighted and the visually impaired, we are giving yet another opportunity for the two groups of children to connect with one another over something.

[54] See Goal Statement: Chapter 1.2
[55] See Background: Chapter 2.3: Psychology of Play and Gamification
[56] See Appendix H: Focus Group Results

4.3.2.3 Every Part of the Toy Must be Identifiable Without Sight

We wanted to design our toy so that a visually impaired person could use it on their own. This meant considering accessibility at every point of our design that they might interact with.

4.3.2.3.1 Tiles

In order to make it so that a blind person could quickly place the Tiles into the base unit, we decided to develop a keying system that would make it so each Tile only fit into one position on the toy, and in one orientation. Doing this would make it so a blind person could very quickly discern whether or not they were placing a Tile where it was supposed to go.[57] This also led to the realization that, when coding any game mode, we would always know which Tile would be in which location. This streamlined our approach when creating the game's logic.

4.3.2.3.2 USB Slot

We decided early on that games would be loaded into the Show & Tell via USB flash drives[58]. Doing this meant that we needed to design it so that a person with limited sight could both find the opening and insert a USB flash drive into it with ease. In our focus group tests, __% of participants were able to insert a USB flash drive without their sight and without having seen the toy before in less than 15 seconds.

We also decided to use USB as the means of storing game data because, in the interest of having as much of the experience be open source as possible, users could download games we uploaded to the Internet onto any household flash drive, and use them in the Show & Tell.

[57] See Detail Design Chapter 4.4.5: Tiles
[58] See: Detail Design Chapter 4.4.6: USB Slot

4.3.2.4 The Physical Flow of Gameplay Should be Taken into Consideration

We wanted to create a space where players could dynamically go between picking pressing buttons, interacting with Tiles, and moving fluidly about the toy. In that, we realized that we did not want to create a situation where game flow was too linear and boring or had so much movement that it was confusing. Again here, we had to take into consideration that our toy itself is a space that the player will grow accustomed to over time. Eventually, they will learn to navigate the toy without the need for eyes. In our awareness of this, we decided to pursue a happy medium so that the user's hands could explore the toy and come to know its space over time, without being too predictable.

4.3.2.5 Internal Mechanisms

In considering how the player will eventually come to know the toy, we realized that including additional points of sensory input doesn't necessarily result in sensory overload, but rather, the stimuli can come together to provide the multiple dimensions of information that would have been communicated by their sight. In light of this, we decided to incorporate elements that might allow the blind to interpret the space of the toy, and each unique game, with additional stimuli that can come together in order to convey the information that would be communicated in the visual appearance of anything.

4.3.2.5.1 Stereo Speakers

Using sound, we can immerse the user into faraway worlds and also present them with information. We can also add to the layers of sensory information is attached each Tile, by using sound things like a lion's roar, a fire truck's siren, or the sound of a basketball being dribbled. By using stereo speakers[59], we also add to the level of spatial awareness that the user can experience relative to the game.

4.3.2.5.2 Cell Phone Motors

We also decided to incorporate cell phone motors into our design, by placing one cell phone motor under each of the Tiles[60]. This gives us the ability to 'highlight' any Tile, and it adds yet another realm of sensory information that the player can use to navigate the toy.

4.3.2.6 Internal Components Should be Serviceable

In addition to taking into consideration best practices for designing a toy for blind children, we also had to design our toy to be modular and easily serviceable by for ourselves. This led to the design of a tray that would hold all of the Show & Tell's moving components[61] . Additionally, we also planned the footprint for how we imagined allocating space for electronic and mechanical components.

In the interest of serviceability, we also pursued components that were low cost, plentiful, and durable. The most expensive item in our Bill of Materials[62] was the Adafruit Wave Shield for Arduino Kit which costs $23.80 as of the writing of this report. By marrying low BOM costs with relatively high cycle rates, a design can only become more feasible to act on.

[59] See Detail Design: Chapter 4.4.7.: Stereo Speakers
[60] See Detail Design: Chapter 4.4.5: Tiles
[61] See Detail Design: Chapter 4.4.2: Button Tray
[62] See Appendix D: Bill of Materials

4.3.2.7 What Information Can the Blind Get through Touch?

After analyzing our results from our test where sighted participants were asked to feel braille sentences and say whether or not they felt similar to the last one they had felt[63], we found that participants were correct 71.4% of the time. This, along with the incredible speed with which people are capable of reading braille, meant that braille was an excellent reference point for the size of a feature that a blind person could feel with their fingers and reliably extrapolate information from. According to BrailleAuthority.org, “Every major braille - producing country has standards for the size and spacing of braille embossed on paper. In the United States and Canada,, the de facto standard is the values put forth in Specification 800, “Braille Books and Pamphlets,” from the National Library Service for the Blind and Physically Handicapped of the Library of Congress.”[64] Here’s a table of the values put forth in that Specification 800, which was last revised in February 2008:

Table 3 Braille Specifications 800

Description	Dimension (inches, millimeters)
Nominal height of braille dots	0.019 inches, 0.48 millimeters
Nominal base diameter of braille dots	0.057 inches, 1.44 millimeters
Nominal distance from center to center of adjacent dots (horizontally or vertically, but not diagonally) in the same cell	0.092 inches, 2.34 millimeters
The nominal distance from center to center of corresponding dots in adjacent cells	0.245 inches, 6.2 millimeters
The nominal line spacing of braille cells from center to center of nearest corresponding dots in adjacent lines	0.400 inches, 1.00 centimeter

[63] See Appendix H: Focus Group Results

[64] http://www.brailleauthority.org/sizespacingofbraille/sizespacingofbraille.pdf

With this information, we were able to begin quantifying the smallest possible topographical information that people can make discernible sense from. This meant that any texture we sought to communicate could, at least, be as small as a braille dot. People who read using braille show us that people are capable of reliably extrapolating precise information from features that are even as small as a braille bump, and they can do it quickly. For us, this meant they any visually impaired person could certainly gain insight into any object that exists in 3-dimensional space through its textures.

4.3.3 Creating the Prototype

4.3.3.1 Design

The Show & Tell was designed using SolidWorks, a parametric 3D solid design tool. With SolidWorks, we were able to act on our desire to create geometric relations between features, and to precisely dimension features based on what we found to be the average size of children's hands. We also used the dimensions of well-designed, commercial products such as Apple's 13.1" MacBook Pro as reference.

In addition to design elements that were made for the visually impaired, we also had to design the toy to be visually appealing and to include design elements that are in line with today's offerings. We had to do this in order to ensure that our toy would be competitive in today's toy industry. After making our initial design, we went to toy stores and took notes on material choice, color palettes, finishes, button shapes, parts, and design elements that were being used.

Figure 9 Top View of Show & Tell SolidWorks Model

4.3.3.2 Alpha

Once our design was completed, we made an alpha prototype. Using 1:1 scalar printouts of our drawings[65], we were able to turn our model into 2 dimensional stencils. With them, we made a cardboard and paper prototype[66].

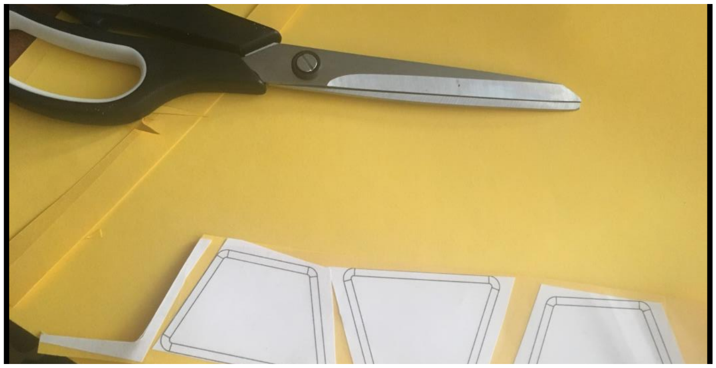


Figure 10 Constructing the Alpha Prototype

[65] See Appendix H: Show & Tell 2D Drawings
[66] See Appendix E: Alpha Paper Prototype

Figure 11 Assemby of Alpha Prototype

With this prototype, we were able to demo physical game flow, the size of the toy, and the size of its components. We made a change log, and after final revisions to our CAD model, we were ready to move on to creating a beta.

4.3.3.3 Beta

Though our model was designed to be manufactured using plastic injection molding techniques, we constructed the body of the Show & Tell using plywood that we laser cut features into. Since our design also had features such as fillets and a chosen color palette, we sanded down the wood and spray painted it to match our model.



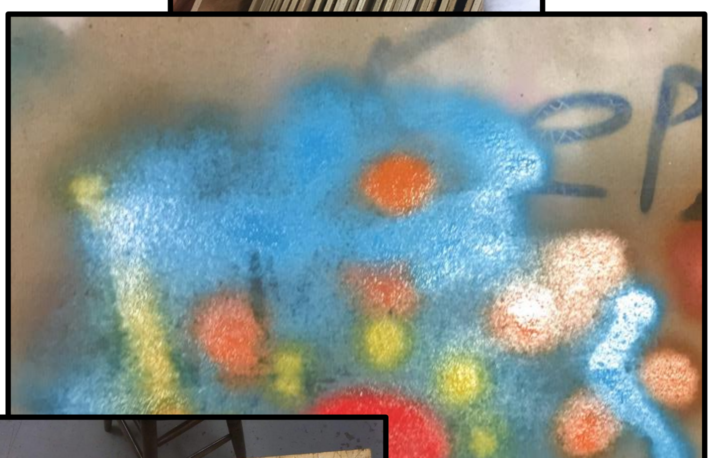



Figure 12 Construction of Beta Prototype

After assembling our beta, we were able to test the mechanisms and feel of the toy. After making a final change log, we gave the design a final round of testing before permanently assembling it, painting it, and otherwise fully integrating its components.

4.3.3.4 Game Concept Development

Once the design had been finalized, we were able to begin the process required to establish the type of gameplay that our toy would provide. This process involved mapping button functions and establishing console navigation, gameplay mechanics and Play Pack variations. Furthermore, once the Play Packs had been established, audio prompts had to be recorded in order to accompany the push of a button in our final game mode.

4.3.3.4.1 Console Navigation & Button Mapping

On the surface of our toy's interface, there are a total of Six buttons. Five of those buttons align to form the shape of an arc, these are known as the *Tile buttons* and are regarded as buttons A to E respectively from left to right. The sixth button is known as the *Menu Button* and lays in the center of the arc created by the Tile buttons. Additionally, it should be noted that each Tile button corresponds to the Tile directly in front of it and are marked by circles shown in figure 16.

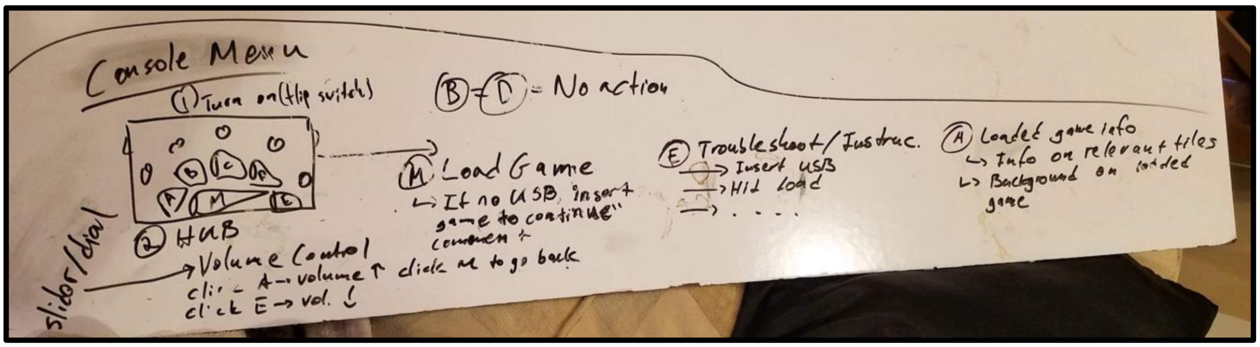


Figure 13 Console Navigation & Button Mapping

Before we were able to tackle gameplay development we had to cement the navigation process of the starting menu, that is, the menu provided when there is no game loaded into the console. As shown in figure16, the functions for buttons B to D are nullified. This was done to minimize confusion and accidental button pressing. Button A was assigned to *Loaded Game Info*, a function devoted to reciting background information regarding the game that is currently loaded into the console. Button E is dedicated to the *Instructions* function, pressing E recites instructions for navigating the starting menu, using a USB drive to load a game into the console and starting a new game. When the user is ready, Button M is pressed to launch the game currently loaded into the console.

4.3.3.4.2 Preliminary Gameplay Concept

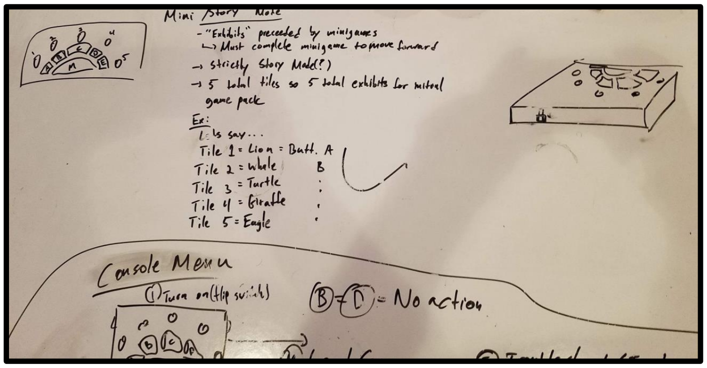


Figure 14 Preliminary Gameplay Concept Development

Our process for gameplay development began with a concept similar in style to that of a standard Role-Playing Game (RPG). The game followed a set timeline, throughout which 5 events, or *triggers*, occur at designated points along the journey. These triggers are represented as circles on a line ordered A to E in the figure below.

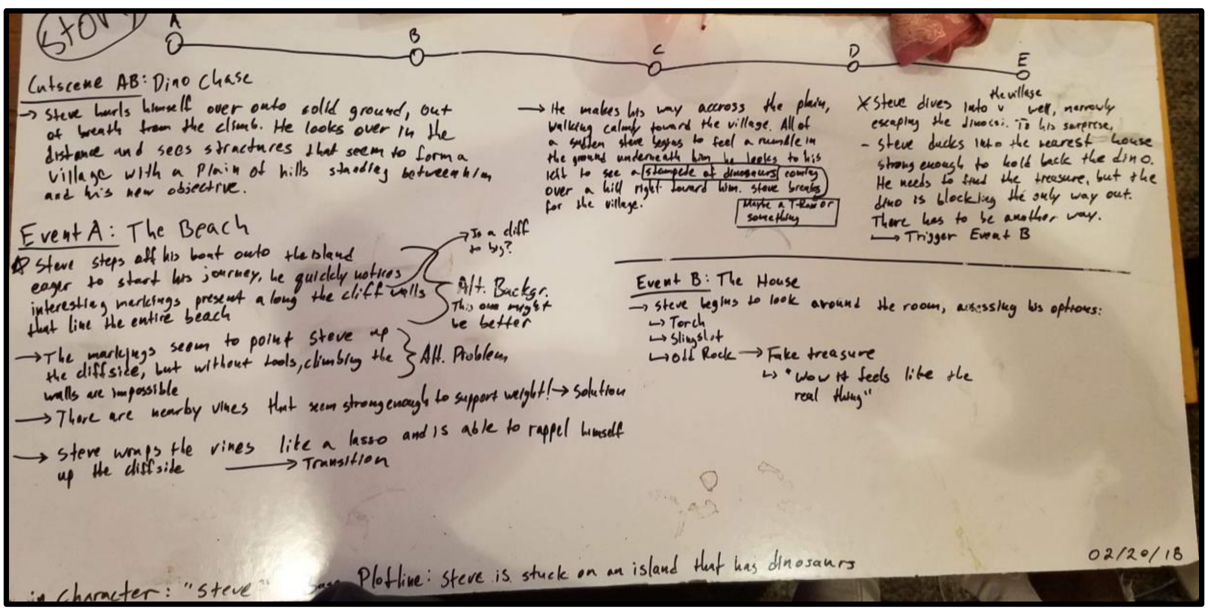


Figure 15 Story Mode Concept Development

Outside of the triggers would be dialogue. This dialogue would be used to weave a narrative in which children of all ages and abilities would be able to comprehend and enjoy. In our case the narrative spoke of Steve, a lone adventurer arriving on an island rumored to be home to living dinosaurs. Additionally, scattered along points in the narrative would be quick-time events (QTEs) or *cutscenes*. These events give the user the opportunity to interact with the narrative by having to press a specific series of buttons in accordance with prompts given from the dialogue. On the other hand, during the triggers Steve would be put into an environment corresponding to the location given in the narrative. In this space, the player is able to control Steve's line of sight using the Tile buttons. The goal during these triggers was to search the environment for any clues leading toward an *artifact*. Artifacts are represented by the Tiles that were previously mentioned. These artifacts acted as collectibles and were required to complete the game. In order to clear a trigger, one must find the artifact in that area. The artifacts themselves would represent different objects with particular textures once again relevant to the narrative. One must then use their tactile senses to feel the artifact and obtain the information required to clear the trigger. Once all 5 artifacts are collected and the narrative is complete, the player has beat the game.

However, soon after pursuing this method of gameplay we ran into a number of roadblocks. The first being the controls. The manner in which Steve would be controlled during triggers felt awkward and after play testing the process of clearing a trigger seemed confusing and tedious. Additionally, the hardware we had initially chosen to use for our toy did not possess the capacity of use required to run the game to the extent we had desired. A simple arduino unit isn't capable of routing commands in the manner we would have needed it to in order to pursue this gameplay concept. Lastly we noticed that, while it may have seemed interesting, this type of gameplay was very linear and narratively driven. We felt that gameplay had taken a backseat to the narrative which, as a result, made it feel less fun and engaging. From our observations, we made the decision to look past this concept and pursue other options for gameplay.

4.3.3.4.3 Secondary Gameplay Concept

Due to the failure of our preliminary gameplay concept, we were now tasked with the creation of an entirely new method of gameplay. This led to the thought of using mini-game based gameplay, a style in which a variety of game modes are present within the loaded game file rather than just one. The premise revolved around progressively difficult gameplay where the user was tasked with using their sense of touch and the toy's Tiles in order to feel out the correct answer regarding the corresponding game mode. From the console menu, the user would be directed to a secondary game menu shown in Figure 19 below.

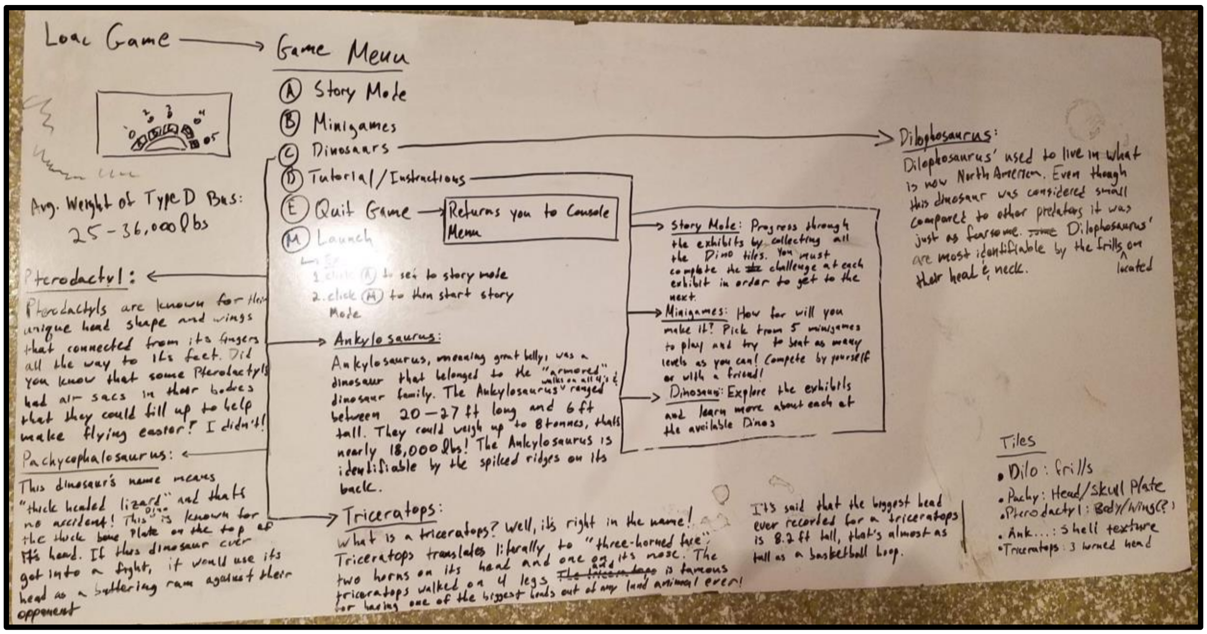


Figure 16 Gameplay Development Notes

Within this menu there are 5 options to select from using the Tile buttons. Button A directs you to the story mode. In this game mode, the user is tasked with navigating imaginary exhibits containing replicas of long extinct dinosaurs. There are total of 5 exhibits, each assigned its own mini-game as an obstacle toward progression. In other words, we had to create 5 unique game modes that were all in the scope of possibility and within the limitations of our toy. We wanted the mini-game modes to be relatively brief and easy to grasp, thus making them capable of retaining the player's attention whilst providing fun bursts of gameplay and knowledge. In order to beat the story mode, the player must complete all 5 mini-games pertaining to each exhibit. Provided in the figure below is a listing of the mini-games we were able create. Underneath the title of each mini-game is a step-by-step progression of that game mode including the story mode as well. As a result, we managed to achieve our objective of creating gameplay variety.

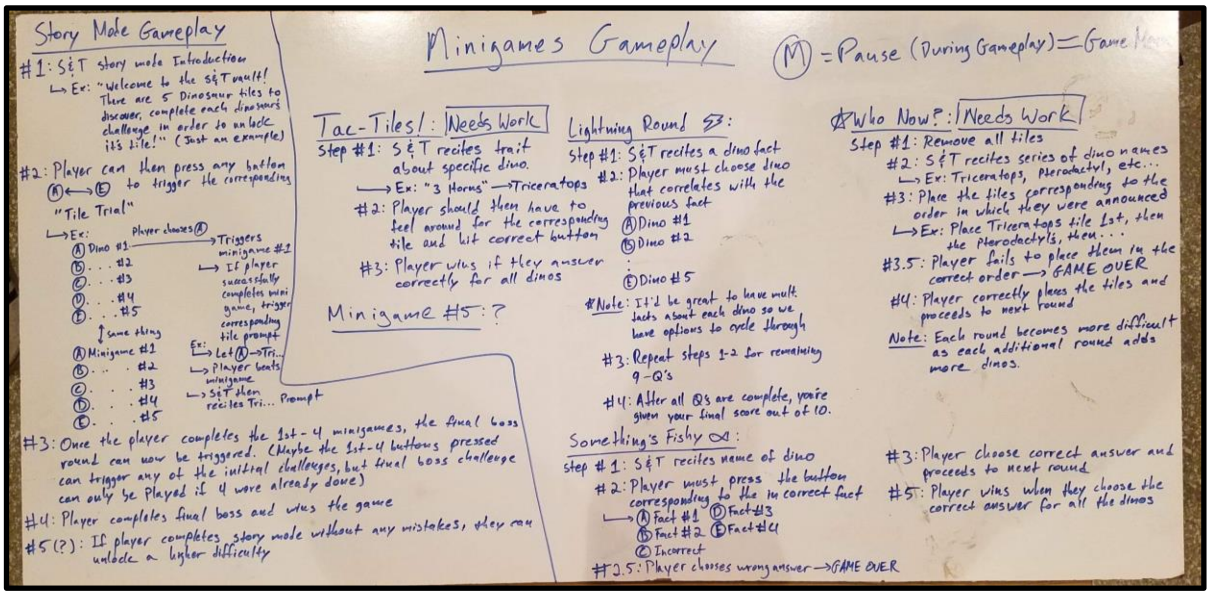


Figure 17 Minigames Mode Concept Development

Pressing the B button while in the game menu directs the player to an alternate mini-game menu shown in Figure 20. While here, each Tile button directs the player to a different mini-game. Simply push the button corresponding to the mini-game you would wish to play, then press the menu button to launch it. After establishing the initial mini-game modes, we wanted to provide additional difficulties to each of the game modes. Whether it be the addition of a timer or increasingly ambiguous fact quizzing, we wanted to add another layer of depth to the mini-games in order to increase replay value. Additional information regarding preliminary concept development can be seen in the figure below.

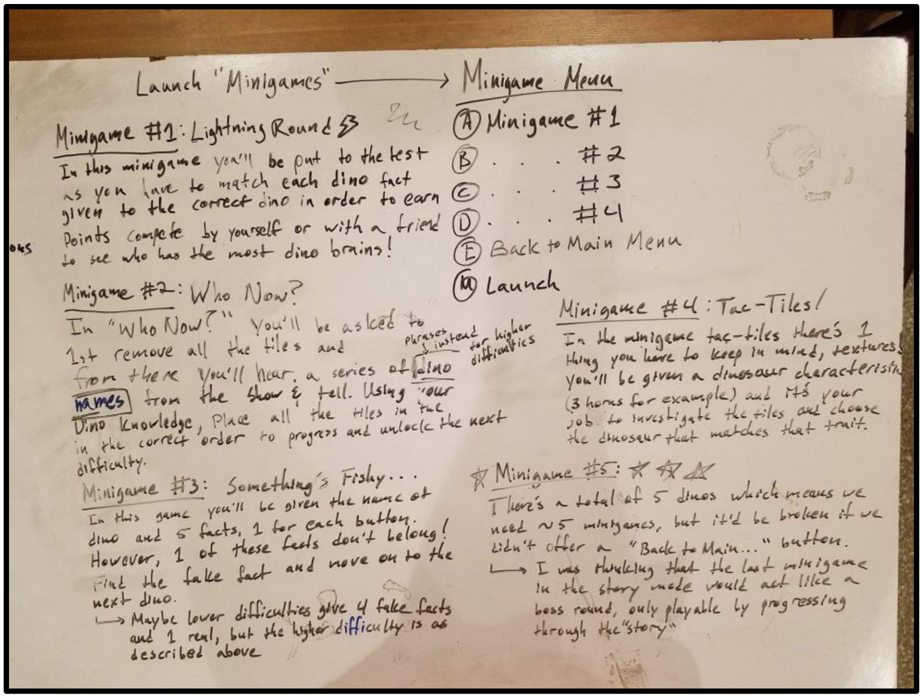


Figure 18 Preliminary Minigames Mode Concept Development

By pressing the C button in the game menu, the player is directed to *Dinosaurs* mode. In this game mode the player is offered a list of dinosaurs to choose from. These dinosaurs are specific to the currently installed Play Pack. Upon launching *Dinosaurs*, the function of each button is converted into playing a recording with various facts and descriptions relevant to the dinosaur of that Tile. This is demonstrated in Figure 22 below. The addition of this game mode provides an optional learning portion to our toy. We feel that by making this mode optional, we're able to prevent our toy from feeling like an AT tool. Each dinosaur for the game was selected on the premise of highly distinguishable physical features. Due to our tactile based gameplay, the more distinguishable and unique each Tile the better the gameplay will function. Features such as "3 large horns" and "large spiked plates" are features capable of being distinguished with respect to the abilities of the children within our targeted age range. The remaining dinosaur descriptions can be viewed in Figure 21 above.

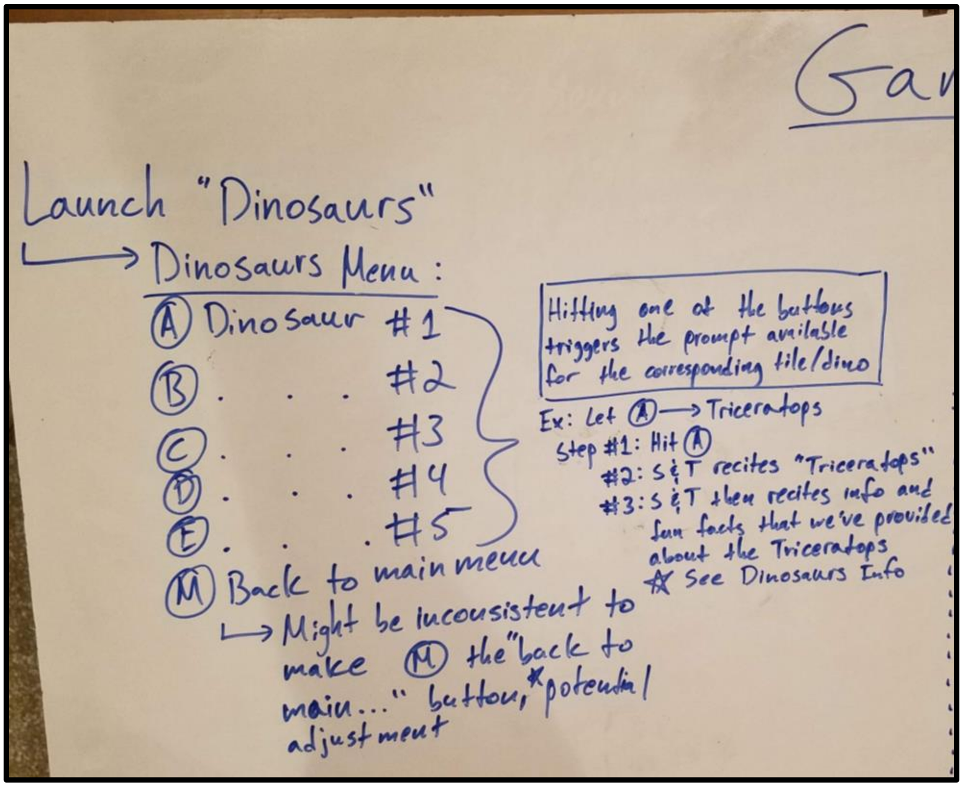


Figure 19 Dinosaurs Mode Concept Development

Unfortunately, while we were able to reach our goal of integrating variety and tactile-based gameplay into our toy, we ran into a handful of familiar roadblocks as well. Once again, navigation felt awkward and confusing at times. Simply going from menu to menu was sloppy and required more effort than it should. Furthermore, the concept of navigable menus using an Arduino based system proved outside the realm of possibility which resulted in a tough scenario. Regardless, we continued to review the results we had created in search of other gameplay options.

4.3.3.4.4 Final Gameplay Concept

Due to the results of our previous attempts at gameplay development, we wanted to be able to create a functioning game mode deemed as sufficient in proof of concept for our design. As a result, we decided to take key features present in the previously created mini-games and meld them together in a simplistic and functioning manner. We had to be extremely conscious of the Arduino's logic capacity when designing this game mode, especially considering our last couple of attempts and their outcomes.

The resulting collective is a game mode similar to one of the previously created game modes called *Tac-Tiles*. In this game mode, the player is tasked with listening to an information prompt following which the user must then use their sense of touch to feel the Tiles and decipher which one in particular presents the correct physical features in accordance with the audio prompt. Each audio prompt is triggered by the push of a button, however, the prompt given by each button varies every time you start a new game. Furthermore, the potential for this type of a game mode is endless. Due to the open source nature of our toy, infinitely many Play Packs can be shared across countries, the contents of which can vary from dinosaurs, to airplanes and bugs to plants. The possibilities for play are endless.

4.4 Detail Design

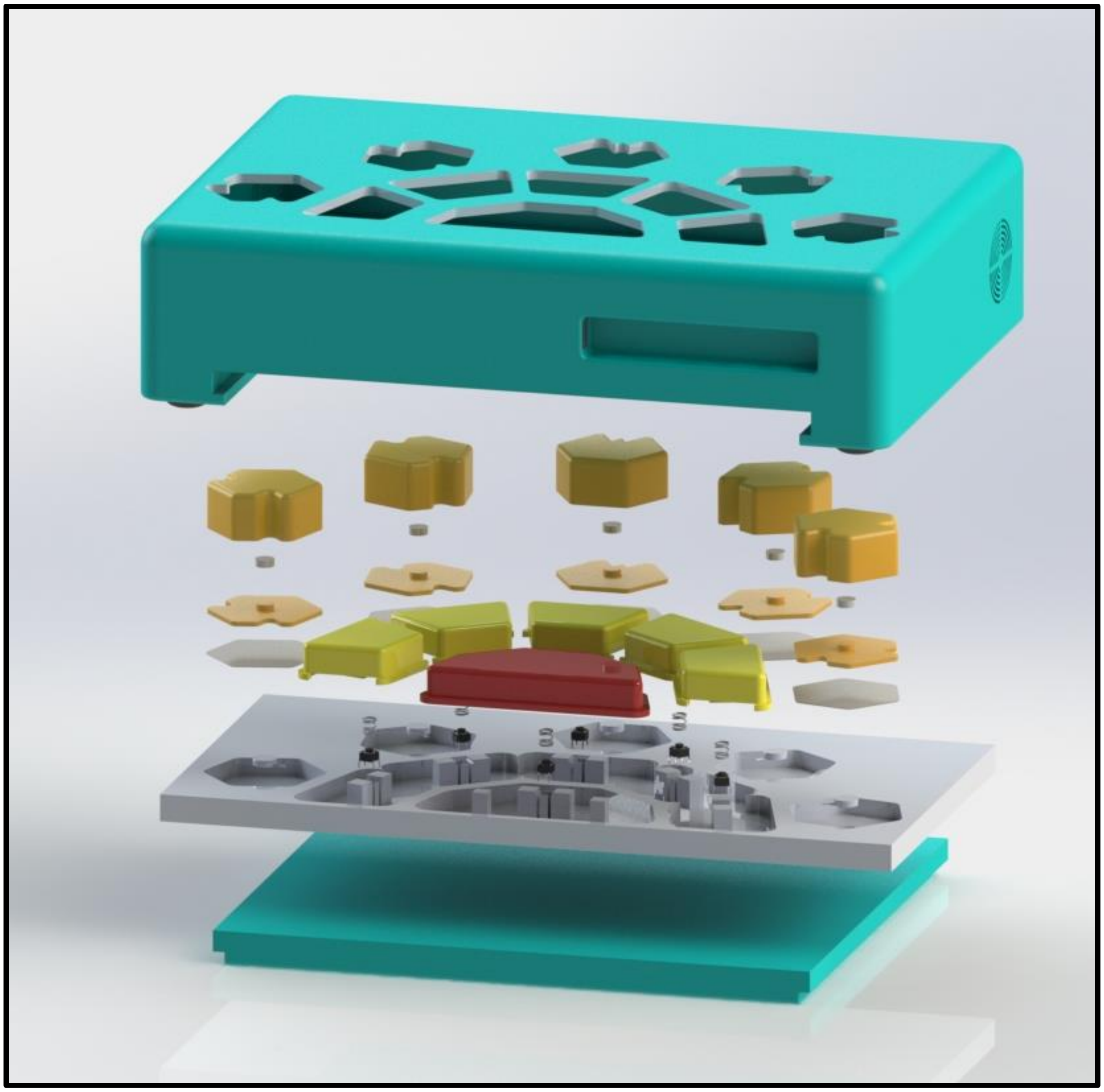


Figure 20 Exploded View of Show & Tell Assembly

4.4.1 Base unit

The base unit of the Show & Tell measures 23 cm x 33 cm x 7.5 cm and contains the processing power and logic of the product. The length and width were altered from the dimensions of a 13" Macbook to ensure that the user, a child with shorter reach than adults, would be able to comfortably reach all of the edges of the top face while playing. The height of the base unit (7.5 cm) was chosen to give the base unit a substantial volume without causing the player to feel over encumbered. To remove any sharp edges from the base unit we have incorporated filets with 1 cm radii on the vertical and top edges as well as fillets of 0.2 cm on the bottom face. The fillets on the bottom face also make it easier for the user to lift the base unit off of a table or other play surface. This is also made easier through the addition of four rubber feet located at the corners 1 cm inward from the edges on the bottom face. These rubber feet lift the base unit 0.5 cm vertically to ensuring that the player can lift the device from the bottom by sliding their hands underneath. The bottom face of the base unit has a sliding door which opens to give access to the internals of the device. This will make maintenance or repair of the product easier as well as make assembly easier. The sliding door was also choses to reduce the number of fasteners required and thus reducing assembly costs.

In our prototype the base unit was laser cut from plywood however in our final product it will be injection molded with plastic. Our prototype also did not include the sliding door component because we anticipated needing to get into the internal components more readily than the average user would with a final product. So instead we created our prototype to open by pulling apart the top and bottom face with the walls connecting via press fit pegs.

The base unit was designed to be main hub of the product and without it one cannot use any Show & Tell Play Packs; However, accounting for the open source capabilities of our product we have designed the base unit to contain all of the needed components to play assuming the player either has a Play Pack or access to a 3D printer.

The base unit has on it a power switch on the back face to the right-hand side from the player's perspective. This power switch is textured to distinguish on and off positions without necessarily using sight. On the right-side face of the base unit on the far bottom corner is a volume control wheel. The base unit holds within it the power supply, processing power, stereo speakers, and a tray with the electrical components. The tray contains the mechanisms for the buttons as well as the electronic buttons to register the click of the button with the device. More on the button mechanics in later the section titles Buttons. The tray also includes five small vibrating motors to give additional sensory feedback. In addition, the tray has as steel cut out for each tie site to give the magnetic Tiles an anchor point. More on Tile mechanics late in the section title Tiles. In our prototype this tray was also laser cut from plywood however our design calls for this piece to be plastic as well.

4.4.2 Buttons

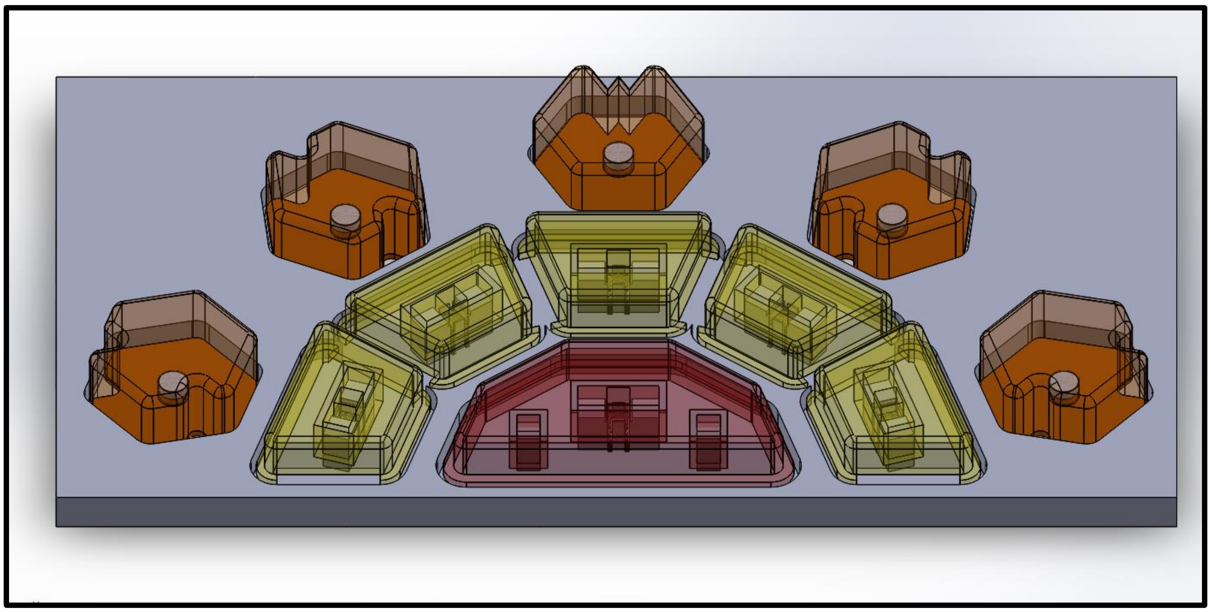


Figure 21 Button Tray with Mechanism

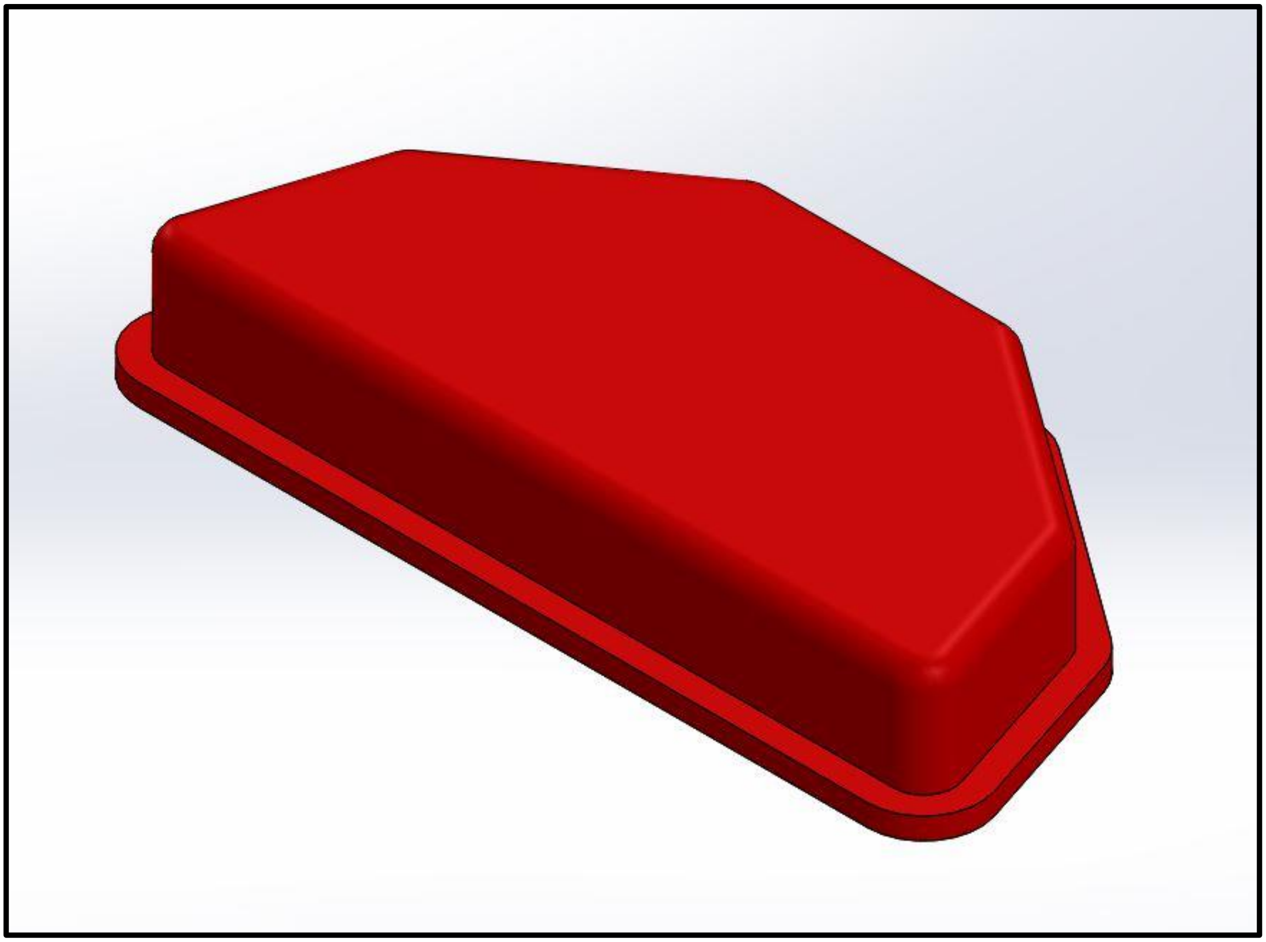


Figure 22 Central Button

Through our analysis of the toy market we noted positive and negative design element of large push buttons for children. One notable conclusion is that many toys on the market have buttons which sway side to side off their path as they are pushed. This made the buttons feel flimsy and like they could break at any moment. This just made the toy feel like a poorly designed product form a consumer standpoint. We noticed that some of the toys had combatted this problem by designing a rail system to guide the button's movement. Another observation we made was regarding the aesthetic and feel of the buttons. We particular noted and were inspired by the theme of curved polygonal shapes and the dimensions of the buttons of the some of these toys. In designing the buttons for our product we wanted to avoid making mistakes that our predecessors had made while also utilizing the fact that we had the opportunity to see all the button designs which particularly seemed to be designed well.

There are six buttons on the top face of our device: five yellow Tile buttons and one red menu button in the center. These buttons allow the player to interact with the game in various ways. The buttons are designed inside of the footprint of a half decagon centered approximately 3.5cm from the midpoint of the front face and 20 cm in diameter. In our prototype, our buttons were 3D printed out of Photopolymer Resin.

To combat some of the unwanted motion of buttons we found in our analysis we designed a rail system with posts for out buttons. The mechanism for our buttons uses posts to guide the button up and down. This guide also helps ensure that the post under the button hits the electronic component to register the button press. There is apost coming downward from the center of each button. This post serves a couple functions. The first is that it sends the signal to the base unit by clicking the electrical tacTile button. This is what sends the signal to the computer. The buttons also has a spring loaded component which ensures that the button will not stay pressed; e.i. The button will only send an input if the button is pressed. The spring and post together also helps to give a comfortable amount of pitch to the motion of the button. The Button design also includes a lip around the base of the button which contacts the underside of the top face while the button is not being pressed. This design helps to keep the button stable and reduces unwanted movement while the button is untouched.

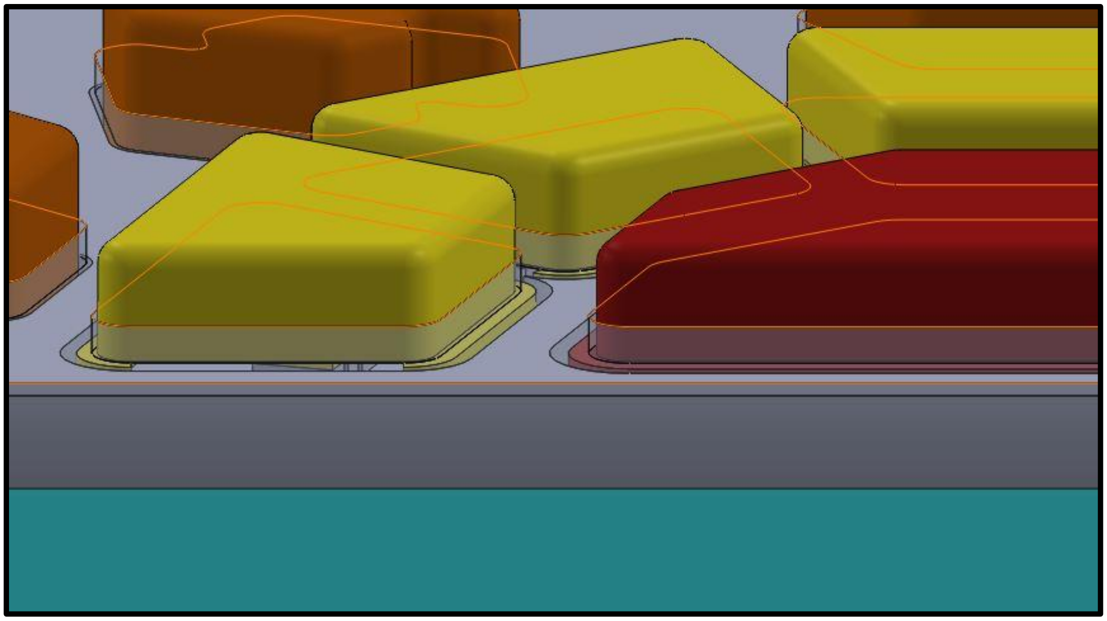


Figure 23 Buttons

4.4.3 Menu/Center Button

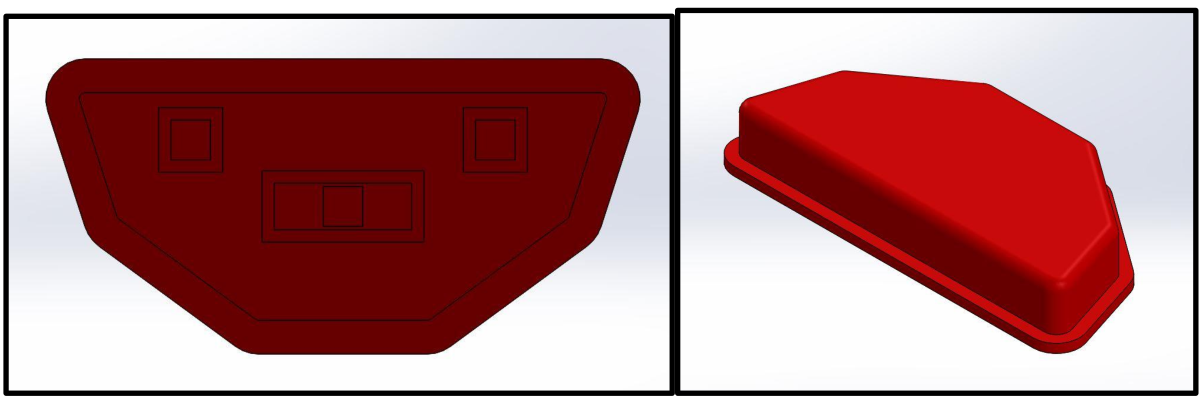


Figure 24 Bottom and Isometric Central Button

The menu button is designed to be the largest button and a natural resting place for the player's hand as they navigate the game. It takes the shape of a concentric half decagon of approximately 9 cm by 4 cm. Due to its larger areas, the center button has four posts where the Tile buttons have only two. We found that larger buttons tended to have more unwanted motion and to deal with this we incorporated two additional post to stabilize the button.

4.4.4 Tile Buttons

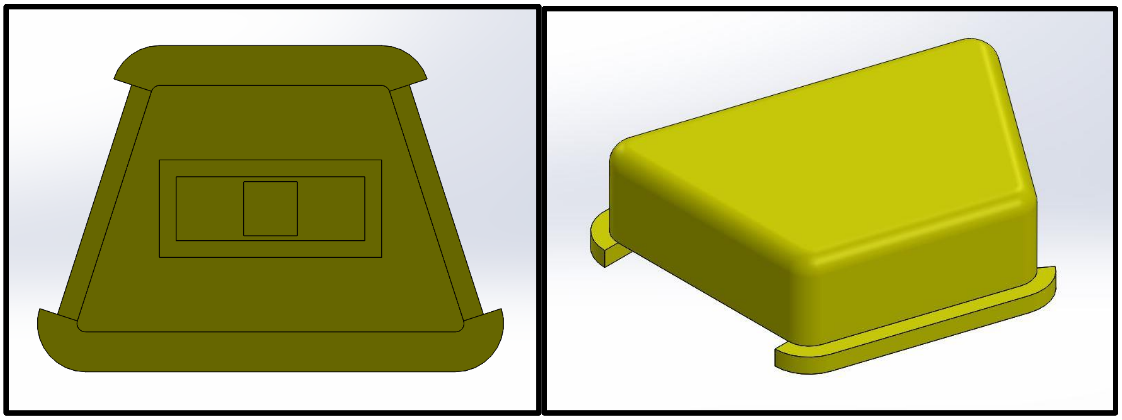


Figure 25 Bottom and Isometric View of Tile Button

The Tile buttons are smaller than the center button measuring approximately 3cm x 4 cm. Depending on the game mode and Play Pack these Tile buttons may be directly associated to a specific Tile. The Tile buttons each individually are shaped like trapezoids with a fillets on each exposed edge. These buttons are smaller in size and thus have less undesired motion.

4.4.5 Tiles

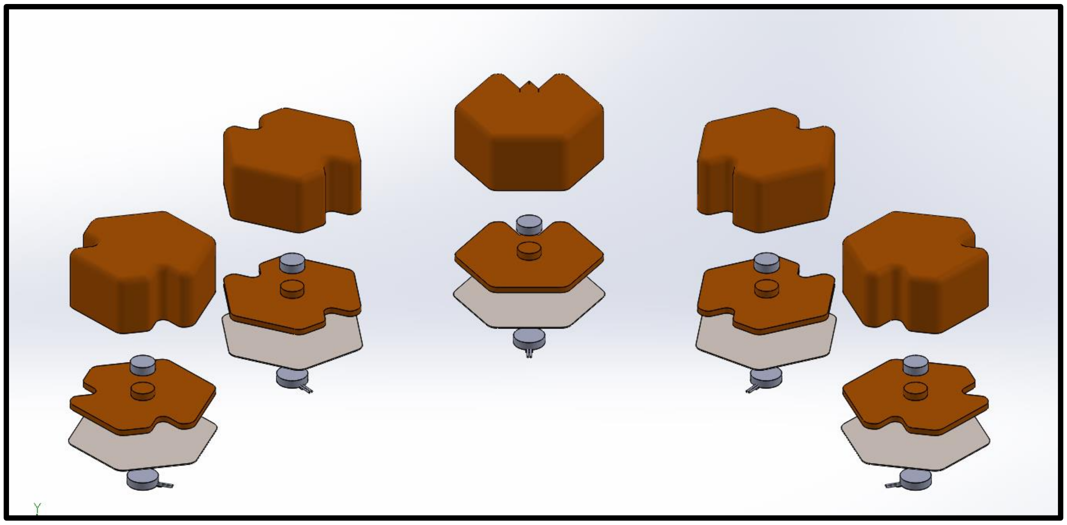


Figure 26 Five Tile Assembly

There are five orange rounded hexagonal Tiles that come with each Play Pack. These five Tiles are each individually unique in shape with an incorporated keying mechanism. The Tiles have this keying mechanism to ensure that each Tile can only fit into its specified location and will not fit into any other. That is to say that if a Tile is to go correspond to position B it will not be able to fit into position D or any other. We achieved this while still being able to keep a “symmetrical” layout of the Tiles. The keying mechanism is created by making triangular cutouts from the edge of the hexagon. We incorporated this mechanic because it is important for our game that the base unit knows which Tile is in which position when it talks about a Tile. This mechanic was chosen over a wireless communication solution because the latter would require that each Tile be manufactured with this wireless communication device. If the Tile can only fit into one position, then as all you need is a 3D printer and you can make your own Tiles by downloading our STL files. Doing this significantly cuts manufacturing costs and improves accessibility. These Tiles are also designed to be able to be removed and inserted with ease. Since touching and holding the Tiles is so integrated into playing with the toy, we added a magnet to our Tiles and steel plate to our base unit to have the Tiles only move when the player is touching them but are easily removed for investigation.

The Tiles you would buy as part of the Play Pack would be different than those which you would 3D print at home. The Tile that are manufacture en masse will be injection molded and incorporate a neodymium magnet. The magnet will rest inside of the Tile but will still be towards the bottom. There is a cut into the Tile where the magnet will go and also a cap that will fit over the whole to make sure the magnet stays inside of the Tile. This magnet would not be included with the STL files as it is not necessary the magnet helps to ensure to Tile locks into place.

4.4.6 USB Slot

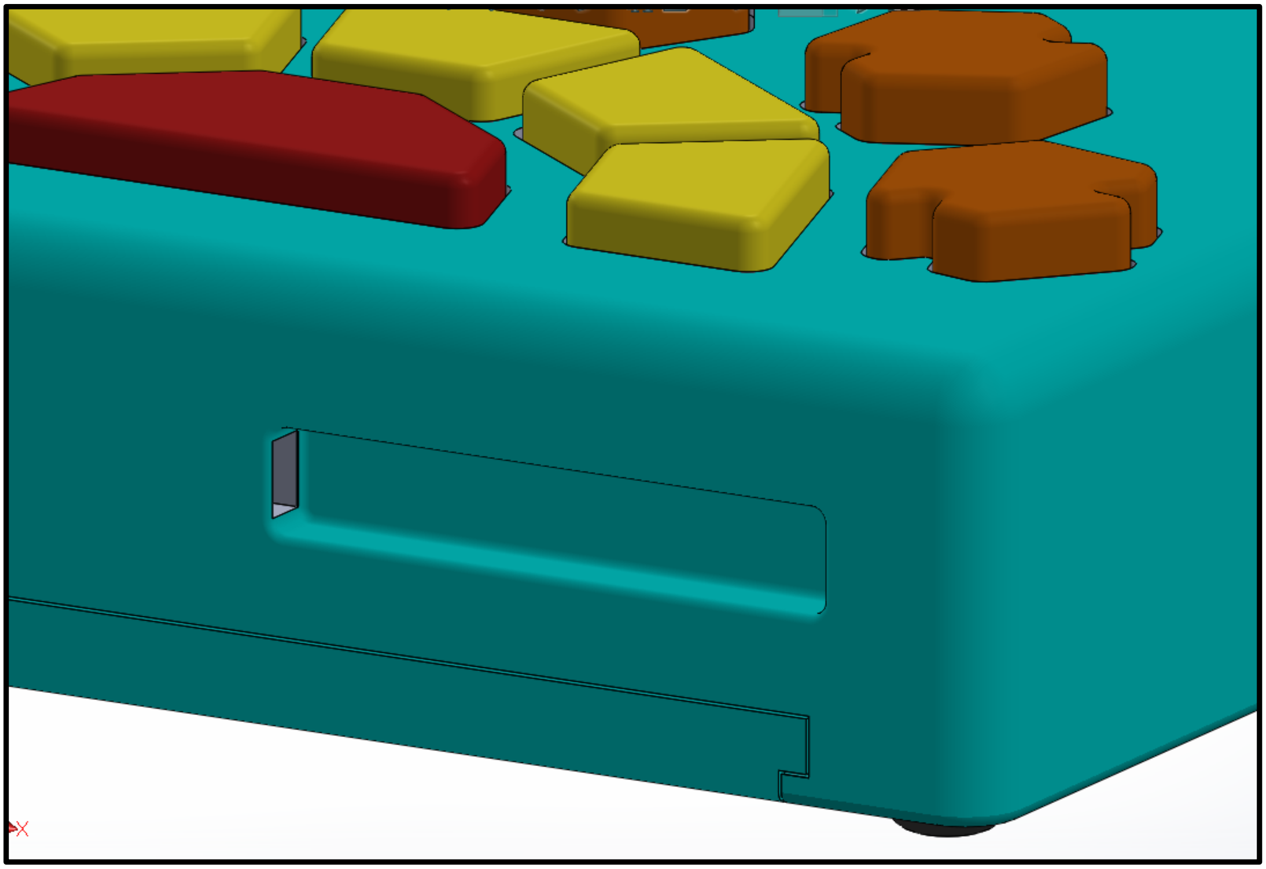


Figure 27 USB Slot on Front Face

The USB slot is where games are loaded into the device. Located on the right side of the front face is an indentation where a female USB 3 port is located. When a Play Pack is purchased or downloaded from our open source files, the audio files and game code for that Play Pack is put onto a flash drive which acts as the game cartage. This was chosen as the location for the USB slot for several reasons. For example, it was embedded into the base unit to avoid any accidental forces acting on the flash drive to break it. This is also a location that is easy to reach and easy to locate. The slot design was utilized to allow visually disabled to slide their flash drive into and down along the slot into the female connection without relying on any sight.

4.4.7 Speakers

The base unit includes two speakers, one on each side face towards the back of the base unit. Designing the base unit to have stereo audio give us the capability to give the illusion of directional audio. By shifting certain audio cues towards the left or right can give the player another layer of sensory feedback on the location a particular Tile in discussion.

4.5 Analysis

To evaluate the design, there are many things which must be considered. A stress analysis will be done to understand the way that forces will interact with our design during regular use. We are interested in determining under what conditions the product will fail. During regular use of our product, temperatures will not fluctuate enough to cause much thermal stress, so we are mostly concerned with structural stress analysis. We will also conduct a finite element analysis (FEA) to simulate physical behavior of a product design. To do this the design must be subdivided into individual components or simple “elements” and then reconstructing the original system from these components. In typical FEA applications, displays are generated as color-coded 3D images. Red will usually denote a failure site, and blue represents areas do not deform under the applied loads. Another analysis to be conducted is a life cycle test. The purpose of doing this is to understand how many cycles the product can withstand before failure. This differs from the previously mentioned forms of analysis in that this tests for fatigue rather than a critical maximum load. This information helps us understand the longevity of our product before maintenance or replacement must occur to continue using the device.

4.6 Test and Evaluation

4.6.1 Alpha and beta testing

We developed two prototypes to help test our concepts. The first prototype was made of paper and cardboard. During our second round of testing we manufactured a wooden prototype with 3D printed parts. We used these prototypes to test our developing ideas, gathering feedback throughout the focus groups and surveys. Through these tests we were able to assess how our solution meets the goal we set forth to accomplish.

We developed a paper prototype to test and evaluate certain key aspects of our design. In creating our first prototype we were able to test things like size and layout as well as the game design elements that we incorporated into the device. The purpose of the paper prototype was to test game mechanics. We discussed the size and feel of the buttons and ties on the top face. By testing the game mechanics, we were able to narrow down which of our game were most fun. Also, after turning towards a paper prototype we began thinking of the texture in our titles. We began to understand what information could be procured without the use of sight. We then explored the possibility of high quality models of creatures and artifacts made from injection molding.

Our wooden prototype allowed us to test even more aspects of our physical design. In our beta testing we incorporated all the components mentioned in our detailed design section. The functionality of the USB slot was represented in this prototype, as well as our Tiles and buttons. These were important features to get feedback on and the data we have gather from our focus groups supported these design decisions. When participants of our focus groups were asked about the overall flow and of the game and placement of features, the majority felt that the placement was appropriate and natural from the player's perspective. As discussed previously in concept development, the design team was conscious to focus on the overall feel of the device during play. During testing of the beta prototype, we gather data from participants showing that our product is visually appealing. Though this is not crucial to the functionally of the device given that our target audience is visually impaired, however, this is good from a marketing standpoint. After considering that our target audience will usually not be the ones purchasing this product we chose to design our product to grab the attention of those who will be purchasing the it as well. After demonstrating and testing our prototype and design this goal was accomplished.

4.6.2 Approving regulations

According to research, a toy that contains swallowable pieces is not legally allowed to be distributed to kids ages 3 and below[67]. This is due to a regulation imposed on the proper labeling of commercial toys. Proper labeling of our toys is important, which is why the data from our survey responses is crucial to understand. With confirmation that we can expect to target an effective age range of children ages 6 to 12, we can effectively mitigate safety hazards, like the swallowing of small pieces, and thus limit the amount of liability that falls back to our group.

4.7 Production

As previously mentioned, for the mass production of the final product, most of the pieces will be injection molded with Acrylonitrile Butadiene Styrene (ABS). Estimates were taken for the cost of injection molding 1,000 units using the injection molding cost calculator at *custompartnet.com*. The tooling, production, and material cost analysis was based on industry

[67] Kuak S and Stein RE. Toy Age-Labeling: An Overview for Pediatricians of How Toys Receive Their Age Safety and Developmental Designations. Pediatrics. 2016;138(1):e20151803 http://pediatrics.aappublications.org/content/pediatrics/138/1/e20151803.full.pdf

averages and typical manufacturing practices. It is important to note that actual production costs will vary based on the specific manufacturer, equipment, location, and market conditions. Estimates were taken for production of each of the five tiles, tile buttons, central buttons, and base units. The total cost to manufacture the parts required for 1,000 Show & Tell units using ABS injection molding is approximately $108,346.02 or $108.35 per unit. Of this total cost, approximately $82,071.18 is contributed by the tooling cost. This includes the molds for each unique part. only one mold is needed for the tile buttons since each of the five tile buttons on the a Show & Tell unit is exactly the same. However, a unique mold must be made for each of the 5 tiles since they are each a unique geometry. Based on industry averages and manufacturing practices, labor and material (ABS) costs for 1,000 units are $10,839.64 and $15,435.09, respectively. Below is a table with cost analysis of each part individually as well as the total cost of the 1,000 unit lot.

Table 4 Injection Molding Cost Estimate

	Material Cost (USD)	Production cost (USD)	Tooling Cost (USD)	Injection Molding Cost (USD)
Base Unit (1000)	$12,386.00	$2,779.00	$27,784.00	$42,950.00
(per part)	$12.29	$2.78	$27.78	$42.95
Tile Button (5000)	$282.00	$1,487.00	$6,015.00	$7,784.00
(per part)	$0.06	$0.30	$1.20	$1.56
Central Button (1000)	$94.00	$475.00	$7,660.00	$8,229.00
(per part)	$0.09	$0.48	$7.66	$8.23
Button Tray (1000)	$1,798.00	$2,309.00	$18,207.00	$22,313.00
(per part)	$1.80	$2.31	$18.21	$22.31

Tile A (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Tile B (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Tile C (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Tile E (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Total (1000 units)	$15,435.09	$10,839.64	$82,071.18	$108,346.02
total (per unit)	$15.44	$10.84	$82.07	$108.35

4.7.1 Product launch

This product holds universal design as a high priority as it is designed to be a fun and accessible game for both visually disabled and visually abled children. Because of this, this product has a future both on store shelves as well as in organization directed towards the visually disabled community. We can envision this product compete with toys in retail locations like Target, Walmart, Amazon, etc. selling alongside typical toys not specifically designed to be accessible to our target audience. We have been in contact with Perkins School for the Blind, a global progressive, multi-faceted organization committed to improving the lives of people with blindness and deafblindness[68], and they have shown interest in incorporating a product like this one into their classrooms. A toy like the one proposed would be able to reach our target effectively through Perkins as they serve around 200 students. Perkins also has a branch called Perkins Solutions which "provides innovative assistive technology products and consulting services to people, organizations and governments around the world to empower people who are blind or

[68] About Perkins School for the Blind (2017)

visually impaired to reach their full potential"[69]. Our innovative product and design philosophy fit this description and would be directly impacting the blind and visually impaired community expand their umwelt and broaden their experiences with the outside world through their sense of touch.

[69] About Perkins School for the Blind (2017)

Chapter 5: Conclusion

The industry surrounding toys for the visually impaired is almost nonexistent; with a limited range of antiquated, overpriced, and under designed options. These qualities amount to products that exploit the people that they were intended to help. We are in the 21st century, and toys for abled children are designed using the latest technology at every step in the design process: the software that's used to design the toys, the electronics and mechanics that make the designs possible, and the manufacturing techniques that allows the toys to become real. Meanwhile, toys that are designed for visually impaired children are often no more than toys for toddlers. To experience play through a toy is more than a feeling of happiness or nostalgia, but additionally, play has massive implications for the development of a child.

Because the blind have all of the cognitive and physical ability that sighted humans do, it becomes evident that there is a gap in the assistive technology market for an engaging, dynamic toy that a blind child could play with and have *fun.* In making a toy that fit those criteria, the problem's complexities quickly unravel. As sighted humans designing something that is intended to be used primarily by those without sight, we are doing our end users a disservice. Rather, our team had to constantly place ourselves in the perspective of our end users (visually impaired children) in order to create a design that was successful ideologically and in its mechanical functionality.

Beyond this, the impetus behind our design was the desire to create something that could connect the blind with the outside world. This meant that we needed to create something that would offer multiple layers -- multiple dimensions -- of discernable sensory output such that the user could recreate the likeness of anything *without using their sight*. As the Show & Tell came together and we reflected on the feedback we had been gathering, it quickly became apparent that by creating something whose goal was to connect the blind to the outside world, our toy needed to be the bridge that separated the two entities. And as such, we needed to be very conscious in our design decisions, because along with coming to know a Play Pack that has (potentially) foreign concepts, the user also must come to know, understand, and navigate our toy. Our toy might even be likened to a 'sensory sandbox,' a place where the user can go and have any amount of senses used in tandem to describe what might have otherwise been described visually. If we could accomplish this, then we would effectively be widening the Umwelt of fellow humans by giving them a new way to interpret information that might be communicated visually. The very same information that a blind person may previously have never been able to experience or interpret, much like we might never be able to imagine what our world might look with a nose as powerful as a dog's, or the ability to use echolocation like a bat.

We wholeheartedly believe that we have succeeded in our goals. By prioritizing a design that was also highly modular (leading to theoretically infinite replay value) and open source (thus allowing the toy reach as many people who might benefit from it as possible), we hoped to not only create something that met our goals but could be sustained for a long time. Even so, there remains a large gap between the current offerings for abled and disabled children. More important than overcoming any technical, mechanical, or design related matter, is the realization that it is possible for those who are in STEM fields to lend their talents toward efforts like this. As a scientific community, and as humans, we have the ability to connect to those around us. Every time humanity has been offered an opportunity to connect with its communities more intimately -- tribes, neighborhoods, letters, telephones, emails, and now various forms of social media -- humanity has lunged at the opportunity. Creating something that might connect the visually impaired to the outside world (and as a consequence, to those around them) is simply another effort at more closely connecting people.

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Appendices

Transcript of Interview with John Rochford

Paul Cotnoir: Hello!

John Rochford: Hello!

Paul: Hello
John, how are you?

John: Just
peachy!

Paul: Great,
John! So, it's Paul and we have the rest of the WPI team here and they'll introduce themselves and then we can get the meeting off. I want to thank you very much for bearing with us, it's taken us a while to get everybody together at the same time here. I apologize if we had a few fall starts.

John: Yeah,
I'm not worried about it. I'm just pleased to be able to help.

Paul:
Fantastic, so why don't we start?

Alexis Gamez: Hi
John! My name is Alexis Gamez, and I'm currently a Mechanical Engineering senior here at WPI. Thank you so much for your time today.

Franklyn Bucknor: Hey
there! I'm Frank, I'm also on the team, and I'm a Mechanical Engineer too. So great to meet you, John!

Miguel Ortiz: And I'm
Miguel Ortiz-- also a Mechanical Engineer. We're all excited to have this time to talk to you about some of our ideas, and refine some concepts for our project.

Paul: So as
the gentleman said, this is a team of WPI students, and our goal is to develop a toy for individuals with low sight, specifically children, that's not only fun but also instructive. And to that end, I think the group has some questions for you.

John: Ask
away.

Frank: Hey
John, it's Frank! In our email we had asked you what it was like to grow up with a visual disability yourself, and you said that you would be interesting in discussing the experience over the phone. We would love to hear your story.

John: Ok.
Well the brief version is that I had full sight until I was 16. I had a head injury, and then lost my sight completely. But over time, I regained it. I saw light first, then I saw colors, and then I saw blobs. So essentially today I am legally blind -- as the vast majority of people who are blind are. A particularly big loss for me was reading. I couldn't read. I was a voracious reader as a child, and the Worcester Public Library had a Kurzweil machine. It was the size of a big photocopier, and I could take a book and put it on the Kurzweil machine, and it would scan the book and read it out loud to me. So that was how I read. After that I had talking books. It wasn't until I was an adult that the first e-readers came out, and with them, I could read voraciously again. I currently read about 2 or 3 books a week. So anyway, I had this huge loss in my life for a long time. But I'm very I don't think of it negatively. It's just something that is a part of life.

Frank: Wow.
I'm really happy to hear that e-readers were able to bring reading back to you, that's amazing. Assistive technology comes in so many forms, and that diversity is part of what makes the sector so incredible. Okay, so, you lost your sight when you were 16 -- which is a bit older than our target audience. Was there anything in your routine or day-to-day life that you found particularly challenging after suddenly losing your sight? I recall that you suggested wayfinding as a direction for our toy development, but is there anything else that you can think of that the blind community might benefit from having gamified?

John:
Frankly, wayfinding for me is still very difficult. I rarely travel alone, but when I do, I'm essentially helpless inside of buildings like airports. In the past 3 or 4 years the airlines have started to do a better job of guiding me, but wayfinding refers to navigating all types of indoor spaces, and it's a **huge** problem for people with low vision.

Frank: Very
interesting. So, one thing that we wanted your input on was: would you say that wayfinding is more of a problem on the scale of navigating a city, navigating a large building (like an airport), or navigating one's home?

John: Well
you see, you can navigate a city using GPS. And, even Google Maps has a feature for walking, that I've experimented with. But wayfinding *specifically* means inside buildings.

Frank: Ah,
alright. In that case, which would you say was more beneficial: Wayfinding in large buildings (like museums and airports and shopping malls), or wayfinding on smaller scales like a person's home? Do you think that there is fence that would be more beneficial to think of this within?

John: Well,
interestingly, I just moved to a new home. And given that that was July 1st -- I'm still having a little trouble navigating
it. Being said, I don't think that's a big use case for you because I suspect that most people, y'know, know their homes well. So I wouldn't use their home, I would use malls or airports or museums. More importantly though, there are several different technologies that are being experimented with for wayfinding. If you could make a toy that would be fun for kids to play and would help them wayfind, it would be a great addition to any wayfinding effort.

Miguel: So would you say John that as far as wayfinding goes ,as implementing that with children starting to develop those skills, would you consider you know would you consider focusing on more immediate obstacles? As far as somebody maybe bumping into something that is unexpectedly in their way or are you thinking something more-- as far as navigating like pathways, hallways, things like this? Or a combination of two, just to kind of think of you know what your ideas here are.

Paul: The idea is to kind of break this down into some real basic kind of skill sets. So is it you know is the basic skill you know collision avoidance, or is it you know trying to follow path markers that are difficult to the parse? So if you had to say, what is the basic skill set that is required?

John: Wayfinding, what it's doing, is it's focusing on different technologies about markers along the way, typically using a cell phone app, to help you navigate inside. Collision avoidance, see that typically is going to be handled by the person-- people themselves with their canes. So, and there have been, as you might imagine, some technology development cane-wise to help with collision avoidance. I think there's an effort in the UK that's been going on for a while that uses a laser range finder I think to help with that. But, anyway, yeah, I don't know what to tell you about a toy for that. I can see maybe, an ascindulator(? - 13:01), an instance where you can expect, when you use wayfinding technology in an airport, or a school, or whatever-- I'm just kind of brainstorming about what kind of toy could be useful for that. But that sounds lame to me.

Miguel: Well, John, we have a couple ideas that we've been brainstorming here are on our end. Do you mind if we just kind of bounce some ideas back and forth see if it maybe gives you some better insight and we can develop some more ideas here?

John: Yeah, sure, go ahead.

Miguel: [Frank], do you want to --

Frank: Sure. So one concept that we've been considering is having a roll out mat, similar to like a twister mat if you imagine that. And the player would have a wearable, perhaps like a bracelet similar to a fitbit. And there would be paths on the mat. We would hope to be able to accomplish something like having a companion app that would allow other players to create new paths --digital paths-- on the mat and so the player that's on the mat would be walking along this path and the wearable would help them navigate it, perhaps with haptic feedback. So it vibrates in the direction that you should be traveling. And then if you would have collided with an obstacle that exists digitally on this map, the bracelet would give you a different type of feedback. And so that could be one "mode" of this wearable -- is the game mode. And then outside of the game there would be a different mode where if you are nearing an object the bracelet will give you some type of feedback so that you don't collide with that object, so it would help you navigate a space like a home. We were discussing earlier when we were coming up with what questions we might ask you in this interview, we were discussing whether it might be more practical to help the blind navigate a city or large building like an airport like you had mentioned or their own home. So we also imagined the idea of having "artifacts" on this map. So, say there's a cube that you have to recover somewhere along the way on this path, and the bracelet will have some kind of other haptic feedback to help guide you to that cube. And so then you pick it up along the way and then you then continue on the path. The practical application of that could be different tags that you can put on objects say like pots and pans or like your coffeemaker and when you wake up if you just want to go to your coffeemaker you can set this bracelet to that and it will direct you then to that object in your home.

John: Yeah, I've been thinking as you've been talking. Should I give you feedback now or wait?

Miguel: Yeah let's go back and forth. We can just kind of build-- we really want to get inside of your head as far as somebody who's more of an expert in this kind of realm, you know. So we'd love to hear more of your feedback along the way.

John: Okay, so my first thought as you were talking, is that, so a big part of being blind is memorization. I memorize-- you wouldn't believe all the things that I memorize. And potentially, if your map could help someone practice a path through a building, like a museum or a school or whatever, I can see that being very useful because they can practice it and then when they're actually in the building then they'll be more familiar with how to get to wherever it is they they want to go, and I can see that being more of a dynamic thing. Now going back to children I don't think that for adults, helping them find their pan in their kitchen is going to be needed because they already know where it is. But for kids, they don't know that stuff about their own homes I bet, and so that might be a use case. You know, kids trying to find things in their homes-- I think that's a good place to do that. I could see that --

Frank: Yeah, I agree.

Paul: I think your target demographic was for younger--

Frank: Yes, so we're designing the toy for younger children. So we do also hope that they'd be able to find these items in their home more easily.

Ideally the wearable would also help adults. Like, an adult could wear this and then navigate a space more effectively. But we are designing it for children.

John: Okay, so I can see-- I think what you have to do is, I don’t know how um -- I guess a kid who wants to cook would be a good person to try with, but you may want to think about how you can appeal to a larger audience.

Frank: Do you feel like the example of one needing to cook kind of exhausts, like, practical uses? Or do you think that realistically some people might want to tag other items like maybe like their backpack or like like items in the bathroom: toothpaste or something, or do you think that--

Miguel: Or for instance the eReader, something like that.

Frank: Yeah, for example, like one’s eReader. Or do you think that, like you had mentioned memorizing, do you think that people quickly like begin to memorize the placement of things. Like is it ritualistic where you leave things in your home, so that you can find them as a person who is visually impaired?

John: Well that’s what I do. And I think a lot of-- well, my guess is most people who are blind do this too. I couldn't -- whatever I do -- Every day I put my wallet in the same place. Every day I put my backpack in the same place. And that's what blind people do. So you know there are those bluetooth RFID chips you can attach to objects to help find them later --

Frank: Yep!

John: Helps with losing my car keys and stuff like that-- but and maybe there's an opportunity to do some wayfinding work there, but I think that for children you have to find something more Universal that would-- to find in their own home that they might want to find that they don't know where it is, and I can't think of anything right now. I mean the kitchen is a good example, like I said earlier, for kids who want to cook. But what else what other things..?

Frank: I feel like it could depend on the person's lifestyle, you know, it could be their backpack, it could be a toy, but I do think that you're right that things don't typically move too far from space to space in the home.

Alexis: I think all in all in the in the process of designing and actually like making a physical product I think one of the one of the def key aspects is universality and universal design and making sure it's applicable to as big of a population or a target demographic as possible, so it's definitely definitely very relevant points. Do you guys have any other questions?

Miguel: Yeah--

John: So y'know I just thought of something. You know that game that people play where somebody has planted in the neighborhood something to find and then there are teams of like adventurers who go to find it.

Frank: Yes, geotag.

John: So that could be-- I think that would be interesting to children to play the game and you could help them figure out how to navigate to those things, that would be cool.

Frank: So like, everyone has like an app on their phone and they go to places in the world and tag those places?

John: 'And so they tag those places'? I'm not sure whether that last reference, I don't know what you mean by that.

Miguel: So by tagging a place, almost leaving an object for someone to find. So now in a digital world if everybody, for example, if this kind of game is done on iPhone platform or something, now I can go on my iPhone and rather than leaving a physical object, maybe tag a location on the GPS and upload that to the group of friends or peers who are playing this and now somebody else can see this geotag and we can get some feedback as far as 'okay maybe now you're getting closer there's something hidden in this general area' and another device can read what somebody else has tagged.

John: Oh yeah yeah, geotagging, that's the game I was talking about I just couldn't remember the name for it. So if that's what you're asking me, that's what I'm talking about. But what I'm saying to you is that for kids who are blind, you have to -- so even if they can get -- so, alright. So an example might be that whatever the 'treasure' the person left might be in a brick. In an empty brick space on the exterior wall of a building.

Frank: Okay.

John: If you’re blind, you can’t-- that’s gonna be almost impossible for you to find. If you’re a sighted person, you can just look at the wall and see where an empty brick is. But, so for example, Perkins within the past year developed an app that -- so Google Maps is good about helping you find a bus stop, say. But what this app does is it helps the blind to-- because within half a-- I know I’m getting a little excited here

Frank: No worries!

Miguel: Totally understand!

John: The Perkins app says to the blind person, cos we have to be able to find the bus stop within a small number of meters right, that Google can’t pinpoint, so the app is a crowdsourced app where people who have been to that bus stop will say ‘find the tree and take two steps to the right of the tree.’ So that could be -- you could build off that, for instance, for the geofinding thing.

Alexis: [Honestly, that’s not a bad idea]

John: I’m just brainstorming here, guys.

Alexis: Yeah absolutely, we're also kinda just trying to digest the information you’re throwing at us, so I guess to put it to something effective-- it's a very interesting concept, I don’t think I’ve heard of that before, and I think that’d be interesting to …

Paul: You know what John, another design consideration that we were thinking about, we wanted a toy that that kids could play at home, that kids that were --you know-- had some sort of a visual impairment could also play with kids that are sighted on an even playing field.

John: Yeah!

Paul: And we wanted something that that had great-- that was a lot of *fun.* So it might have some occupational therapy sideline to it, but really the first consideration was that it'd be fun and something that kids would like to do and enjoy doing.

John: Yeah, so I think this idea meets those criteria.

Paul: No I think it does. So it's almost like a blind man's bluff, or pin the tail on the donkey kind of activity, right?

John: Uh, sure.

Paul: I guess the point-- what I'm saying is, from the perspective that those gains-- the sighted players are basically on an even playing field with individuals who have less than perfect eyesight. And actually the people with certain types of vision loss may actually have an advantage in a situation like that.

John: How so?

Paul: Maybe because of the heightening of their their other senses? Their awareness of the environment outside of what is just purely visual.

John: Yeah.. So I just want to caution you a little bit that it's a myth that people with poor eyesight or who are totally blind have better other sense. But the reality is that they just pay attention to them more than people who are sighted do. So I just wanted you to keep that in mind.

Miguel: Going off of that, would you feel that rather than having some kind of added benefit and almost-- you know I know myself as somebody who is not visually impaired. When I put on a blindfold it's not so much that I lose my sense of sight, it's more so that it's disorienting to me. And I think that one of the ways that we were considering simulating low vision to a sighted person playing this game, to even the playing field would be something along the lines of putting a blindfold on them. Would you think that in that sense maybe it would be less disorienting to the visually impaired person, or do you think that that would keep them on an even playing field? As far as visually impaired versus visually, you know, sighted individuals.

John: Yeah, so when you blindfold yourself, then you're simulating the-- for people are totally blind which, as I mentioned on my email, they are less than 10% of people who are blind. But, a cool thing is that there are glasses that you can wear that can be configured to mimic different types of vision loss. So the potential here is that you could configure those glasses to your fellow contestant's level of vision of loss, then that would be an equal playing field. Or, a more equal playing field.

Frank: Very cool. That kind of makes me think about like a grab-bag of different goggles that all have different levels of vision loss.

John: Yeah that would be-- yeah that would be a cool thing.

Frank: Then the players would all have to sort of wrestle with different types of vision loss, and maybe they can be modeled after the different-- because I remember I -- I worked with the Seven Hills Foundation for a term, for a project my junior year that I became-- I don't know if you happen to know an individual named Erin Fragola, he's like an outreach coordinator for the Perkins library so we became very close. And I remember he had like this business card for an organization, but in the business card there were cutouts, and you could like look through them, and each one had like different kind of shapes that would block parts of your eyesight to simulate the different types of visual impairments a person can have. So it was pretty, I mean, 'cool,' but it was very interesting to see that blindness is not one size fits all by any means.

John: Well, I have to say that I've considered myself 'cool,' for a couple of, I don't know maybe four years.

[Laughter]

John: I'm thinking now that I really want you to connect me with that guy because I really want to get that business card.

Frank: Most definitely.

John: So please do. He actually had a whole kind of cast of like assistive devices for the blind. Like he showed these maps for the blind that have like different texture keys for like rivers and mountainous regions and things. All kinds of like cool things I had never seen before. It was an assistive technology fair that we coordinated, and so he was showing off all the assistive technology that exists the blind that's both low tech and high tech, and he had a bunch of stuff. Some really old stuff even, so probably a lot of stuff that you'd be interested in seeing.

John: Well Easter Seals, which is in the Denholm(sp?) building on Main St in Worcester, has an Assistive technology lab --

Paul: [We were there at the Grand Opening.]

John: --full of devices that people with disabilities can borrow and see if the device is good for them, so that might be a place you want to visit to see what's possible.

Paul: Yeah we were there grand opening, John.

John: Oh, okay! Great!

Paul: And we met Robert B'Lanna, right, is the director? And Randy Sargent. Yeah.

John: Yeah I know Randy but not Robin. So uh, just as an aside, let me think about how to say this well, so you guys know about Special Olympics right?

Frank: Yes.

John: Okay so it's you know it's every four years along with the Olympics are Special Olympics. And a really terrific thing that Special Olympics started to do about, maybe 12 years ago or so, is that it would provide-- before the games-- they would bring in physicians and dentists and ophthalmologists and all kinds of health service professionals and it will provide health care to the athletes who many of whom have never have had health care in their lives.

Frank: Oh, no way.

Miguel: Wow.

John: Yeah. And there was-- so what happened is --so you get an ophthalmologist who would be able to gauge someone’s vision and give them glasses. And then they’d have to order them and then try to get them to that person later, right? And it was a terribly long process until a very cool invention. What it is essentially is two thin layers of glass -- or two layers of glass-- and in between the layers of glass is a thin thin space filled with liquid. So essentially the ophthalmologists would be able to judge, you know give the eye exam, and then freeze the liquid at the prescription.

Miguel: Wow.

John: Instant prescription glasses.

Frank: That's insane, I’ve honestly never heard of that.

[chatter]

Frank: You just shocked all of us. That’s really crazy.

John: Yeah! So I’ve been working for the past year now with a very cool agency called vision aid in [ ], India. So in India, as you know, I hope, there are millions and millions of people who are very poor. And people who are blind, and I mean across the spectrum of blindness, basically their occupation is begging. And or they can't go to school, they can't get jobs, there’s no help for them. And so vision aid has been doing some things such as building schools for these people. And also, getting them glasses. And so, because unless it incredible how [ ] this is, but these people -- adults who -- just by getting a pair of glasses, their vision problem goes away, because now they can see. As adults, because they were too poor they could not afford glasses.

Frank: Yeah, absolutely insane that they don’t have the level of infrastructure as far as health insurance goes.

John: Yeah, there’s nothing like that for these [big??] population.

Frank: Yeah, I lived in the middle east for a couple years and there were--

John: I went to a fundraiser in Littleton, Mass. a few months ago for this agency and it raised enough money in that one fundraiser to start two schools.

Frank: Very cool.

John: Yeah it is very cool. And they're a very ambitious agency, they help-- so every year I run a visual accessibility conference that IBM has been hosting for the past few years.

Frank: Oh, that’s awesome. What’s it called?

John: The Boston Accessibility Group conference. We have a meetup, actually this Tuesday, we’re gonna be talking about a framework called [chat]figuration that builds applications from the ground up to be accessible. Web apps. If you could come, you’d get to learn a lot and you’d also get to meet folks from vision aid. And I think they would be a great connection for you because, as I was saying to you in my message, you have to think -- I think you should think internationally. And how you can be helpful-- I get excited about all of this stuff, and I'm just realizing now that even though I'm saying all this to you and trying to get you excited about it, that I imagined this is your MQP project so this is going to be like a one-and-done thing for you. But if, you know, I hope that you become interested enough and this stuff excites you enough that, you know maybe later that even after you graduate this might be something that you could -- in one way or another -- be helpful in. Because corporate America-- working for corporate America is a great thing, sure, but how often--

Frank: You're preaching to the choir.

Miguel: On behalf of all of us, we're definitely very passionate about this and we definitely did not take the decision to take a project like this lightly. We're all incredibly invested in this. You know in this whole, everything this entails, really. And I think that's across the board, all of us.

Alexis: I think we've all realized, kind of, the impact that this project could potentially have. And knowing that impact I think--

Miguel: As well as future projects.

Alexis: Yeah. It just further attaches to the idea and we're definitely kind of all-in it at this point.

Frank: Yes, and we've been in touch with Perkins. In the past I designed like a toy for blind children last year and we got in touch with Perkins engineers. And they floated the potential for integrating this into their classrooms. Like, the avenue exist such that a toy designed by WPI students could have that end goal, and they service blind children internationally which is really cool to think about that possibility. So with an opportunity like that we'd love to design a toy that was great, and accessible, met goals; such that an organization like Perkins could take it up and get it to blind children that could really benefit from this toy.

John: Well I think, going back to the geo location adventuring, that's also as you may know that's also international. And so you know that one idea could be-- you could do all that, I think, could be a broad application like that.

Frank: Right on we'll definitely look into it.

Alexis: Hey John, by any chance do you mind sending us, or maybe even Paul here, some info on that Boston accessibility group conference just in case. I'm not sure if we would be able to make it this week just cos it's kind of short notice, but if you really do think these are some great contacts to have, if we should really pop down, if you think it's a great source of information, we'd love to plan it out in advance and that way we can be maybe like schedule a day or a night depending on where it is -- or when and where it is-- to see if we can kind of you know take some time out of our day and actually you know attend and show face and see what the going ons are.

John: Yeah, well, I'm the organizer of it. So I'll send you the meet up page for it. It has all the details about it.

Frank: Thank you very much.

Miguel: Excellent.

Frank: And then regardless of our availability this time around we'd love to maybe like set up another meeting with you in the future, and talk about concepts with you perhaps face to face if you'd be available. And then we can show you sketches, and it'd be easier to navigate our ideas, and we can have like smaller prototypes etc. We're also looking at putting together focus groups and Clinics for our prototypes and we have some contacts at the Perkins school for the blind -- the library outreach coordinator that I mentioned and one of the engineers for their Perkins design group-- and we have contacts with Seven Hills and Easter Seals as well, but if you happen to know anyone who would be able to weigh in on this sort of thing, and would be interested in participating in like a focus group, that would be really great information to have.

John: Okay. So guys, I [run] the information of the [servicism bay] for people with disabilities. So we have thousands of listings of doctors and dentists and programs and services for people with disabilities. And we have a network of over 140 non-profit agencies that serve people with disabilities and also [direct information] referral. Basically, if you send me the blurb about whatever it is that you want, I'll get it posted through our network of agencies and also it'll go out to social media and it'll reach tens of thousands of people with disabilities.

Frank: Right on.

John: So we can do that. I am as we are talking constructing a message about the meet up, also I already sent you a link to the Perkins App -- some articles about it, it's just a little search link.

Frank: Sweet, thank you so much. I'll make the connection with the individual I was mentioning earlier.

John: Sure. What I'm just saying to you is if you want to publish anything, like you were asking me, just send me whatever it is you want and I'll put one of my staff to post it for you.

Frank: Awesome thank you so much, we really appreciate it.

Alexis: [I think that's all the time we have today…]

Paul: Okay yeah I think these guys have to get back to another class John, but this has been extremely instructive and we really appreciate you giving us of your time today.

Frank: Thank you so much it was very very helpful.

Miguel: Yeah thank you John and hopefully we can have another call like this or a face-to-face meeting in the future.

John: Yeah sure, I'll do that with you. And I hope that you know you guys can make it to the Tuesday meeting and I'll meet you in person there. And also the stuff, you said you'd show me sketches? Okay, so remember I'm legally blind, so..

[laughter]

Frank: Well he mentioned that was recovering -- I -- I -- I'm sorry.

John: Well I mean you can show me sketches, I'm just saying make it digital and then I can blow it up on my 55" monitor. Y'know?

Frank: Perfect!

Miguel: Excellent!

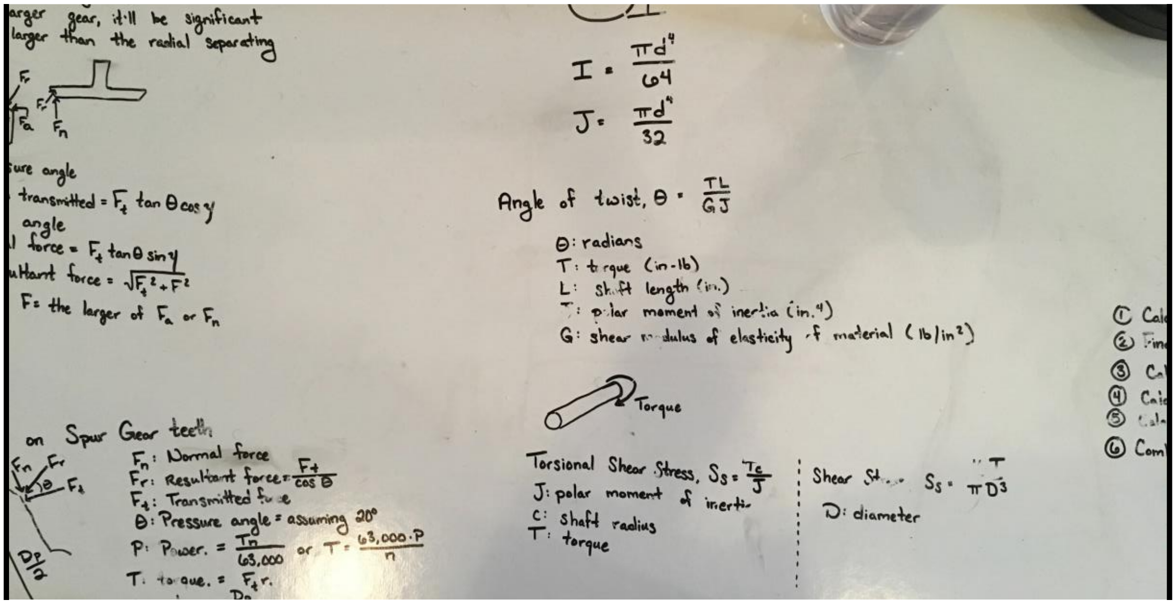
Paul: We can do that, thanks a lot John!

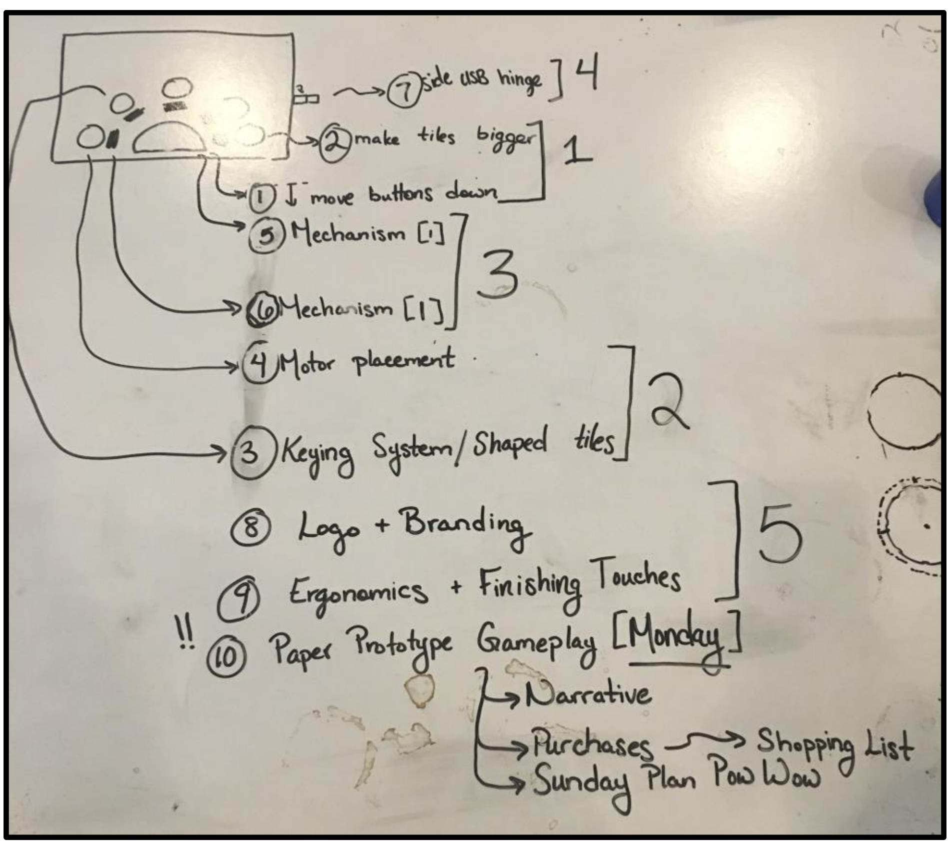
John: Okay, ciao.

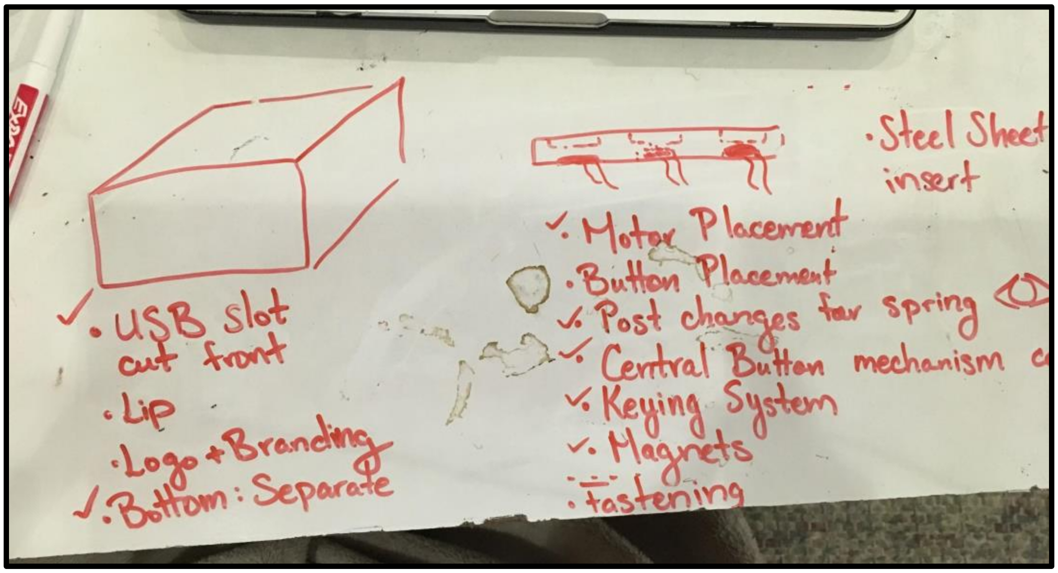
Appendix A

Appendix B

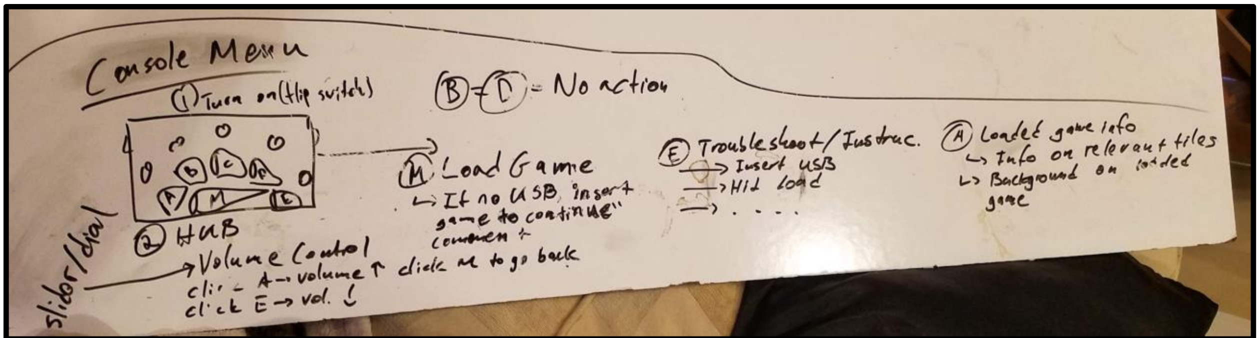
Whiteboard Pictures

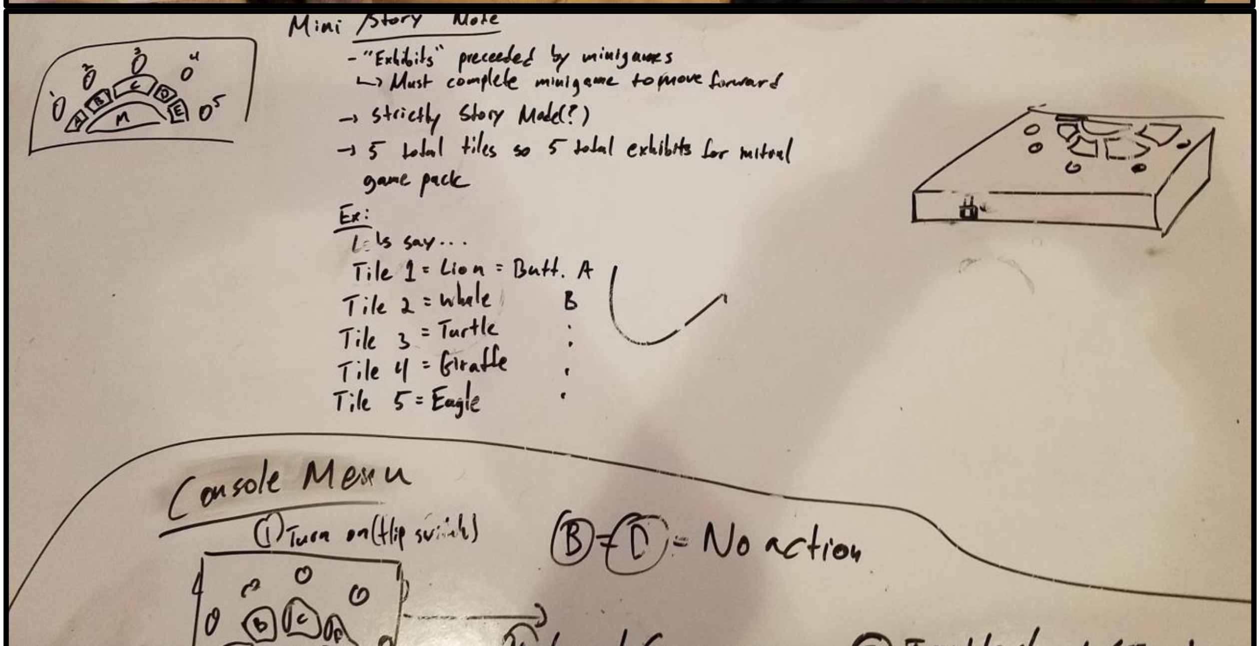


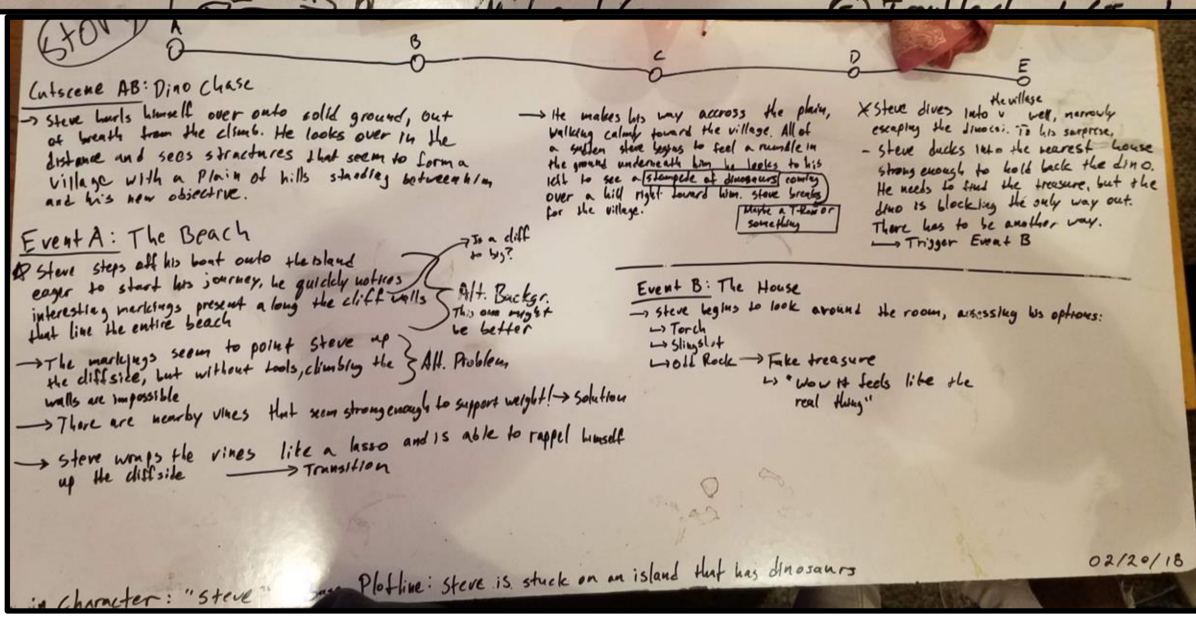


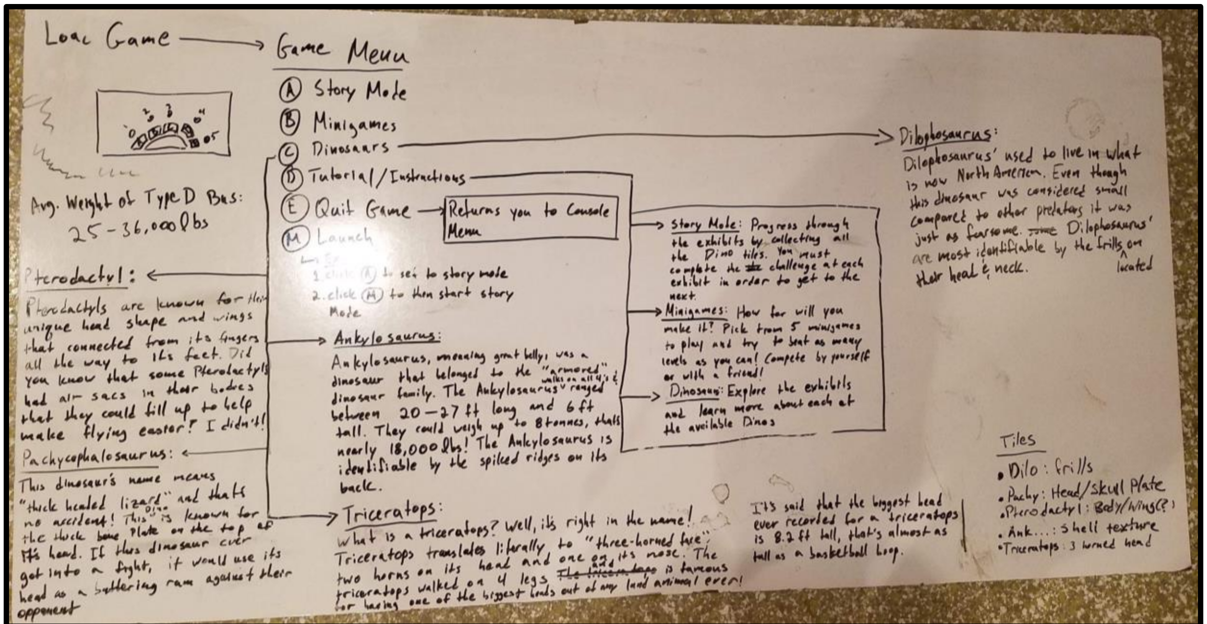

✓ • USB slot
cut front
• Lip
• Logo + Branding
✓ • Bottom: Separate
✓ • Motor Placement
• Button Placement
✓ • Post changes for spring
✓ Central Button mechanism
✓ • Keying System
✓ • Magnets
• fastening
• Steel Sheet
insert

Whiteboard Pictures for Game Development

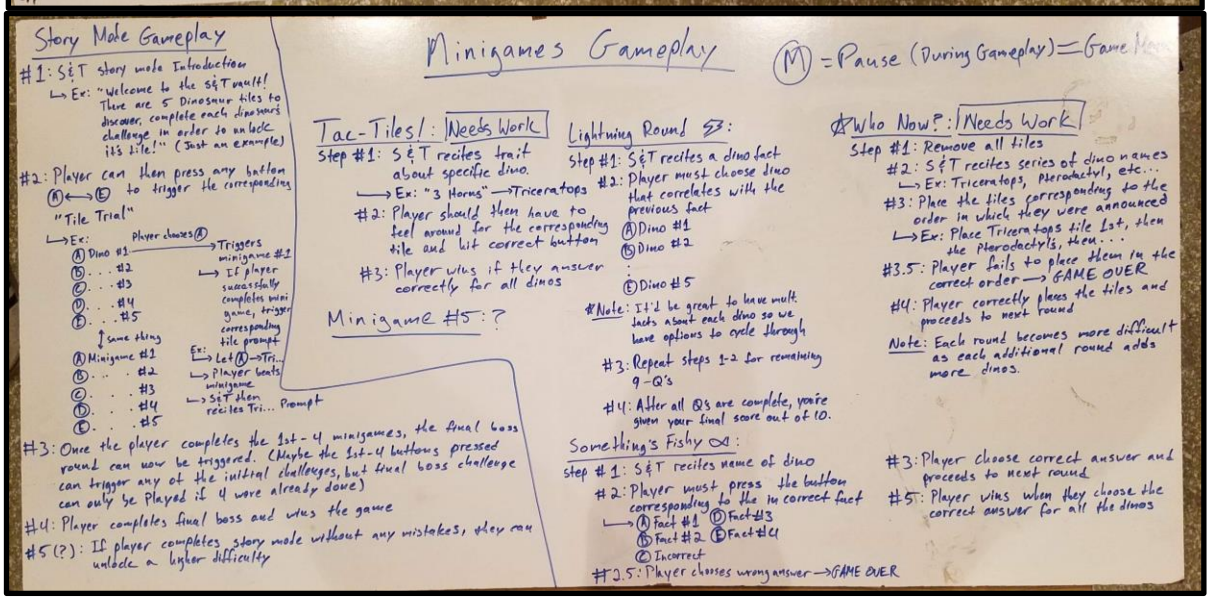




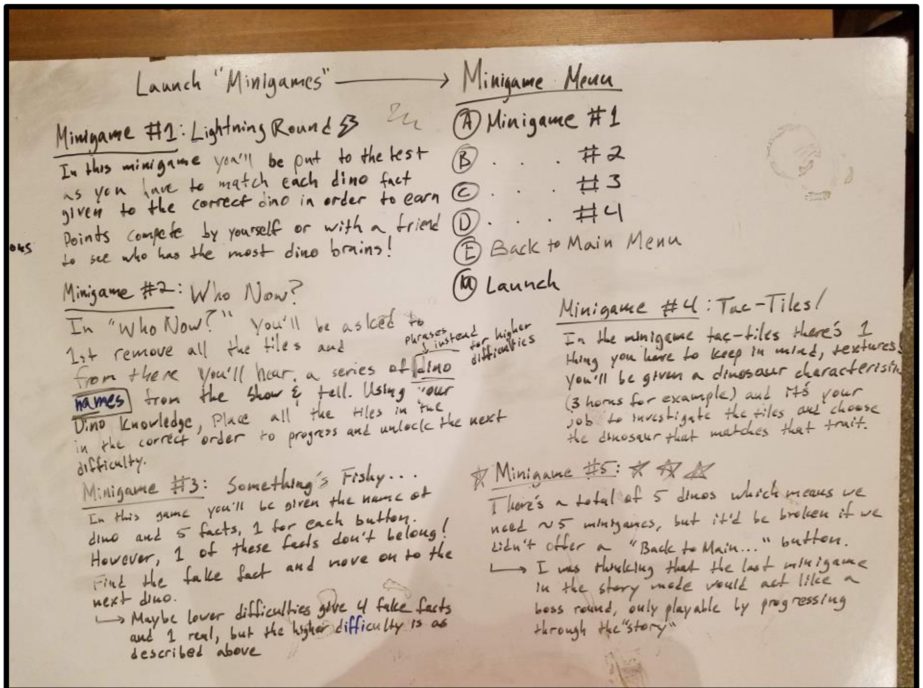


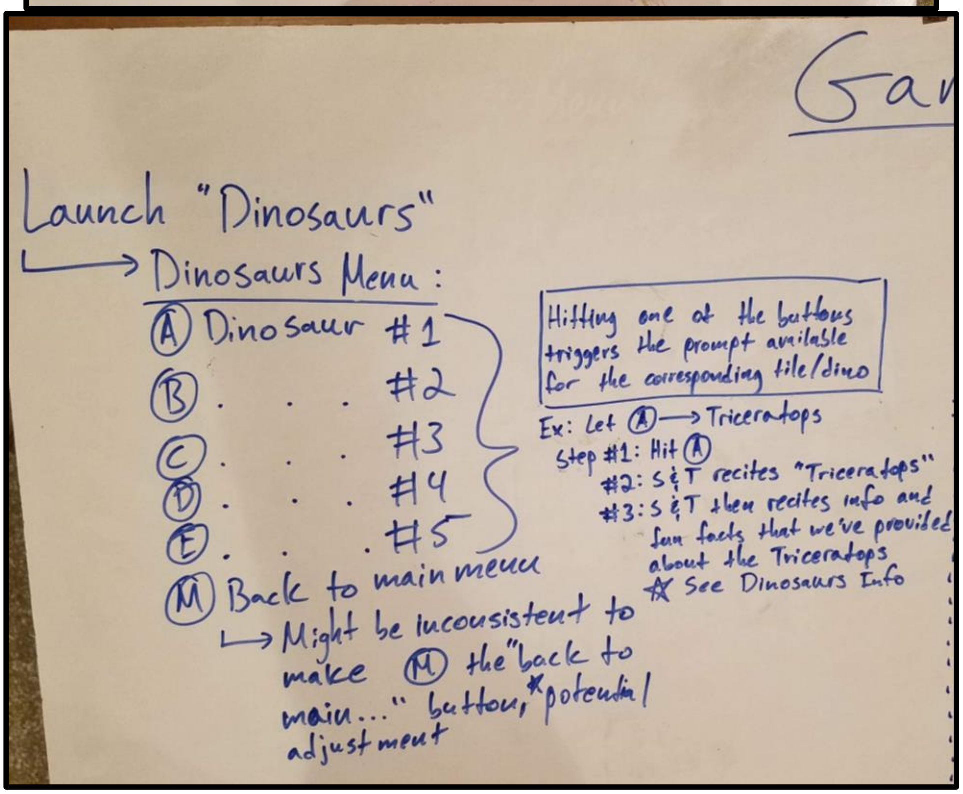


Loac Game
Game Menu
(A) Story Mode
(B) Minigames
(C) Dinosaurs
(D) Tutorial/Instructions
(E) Quit Game
Returns you to Console Menu
(M) Launch
1. click (A) to set to story mode
2. click (M) to then start story Mode
Avg. Weight of Type D Bus: 25-36,000 lbs
Pterodactyl:
Pterodactyls are known for their unique head shape and wings that connected from its fingers all the way to its feet. Did you know that some Pterodactyls had air sacs in their bodies that they could fill up to help make flying easier? I didn't!
Pachycephalosaurus:
This dinosaur's name means "thick headed lizard" and that's no accident! This dino is known for the thick bone plate on the top of its head. If this dinosaur ever got into a fight, it would use its head as a battering ram against their opponent
Ankylosaurus:
Ankylosaurus, meaning great belly, was a dinosaur that belonged to the "armored" dinosaur family. The Ankylosaurus walks on all 4's & ranged between 20-27 ft long and 6 ft tall. They could weigh up to 8 tonnes, that's nearly 18,000 lbs! The Ankylosaurus is identifiable by the spiked ridges on its back.
Triceratops:
What is a triceratops? Well, it's right in the name! Triceratops translates literally to "three-horned face", two horns on its head and one on its nose. The triceratops walked on 4 legs and is famous for having one of the biggest heads out of any land animal ever!
Story Mode: Progress through the exhibits by collecting all the Dino tiles. You must complete the challenge at each exhibit in order to get to the next.
Minigames: How far will you make it? Pick from 5 minigames to play and try to beat as many levels as you can! Compete by yourself or with a friend!
Dinosaurs: Explore the exhibits and learn more about each of the available Dinos
Dilophosaurus:
Dilophosaurus' used to live in what is now North America. Even though this dinosaur was considered small compared to other predators it was just as fearsome. Dilophosaurus' are most identifiable by the frills located on their head & neck.
It's said that the biggest head ever recorded for a triceratops is 8.2 ft tall, that's almost as tall as a basketball hoop.
Tiles
• Dilo: frills
• Pachy: Head/Skull Plate
• Pterodactyl: Body/Wings(?)
• Ank...: Shell texture
• Triceratops: 3 horned head



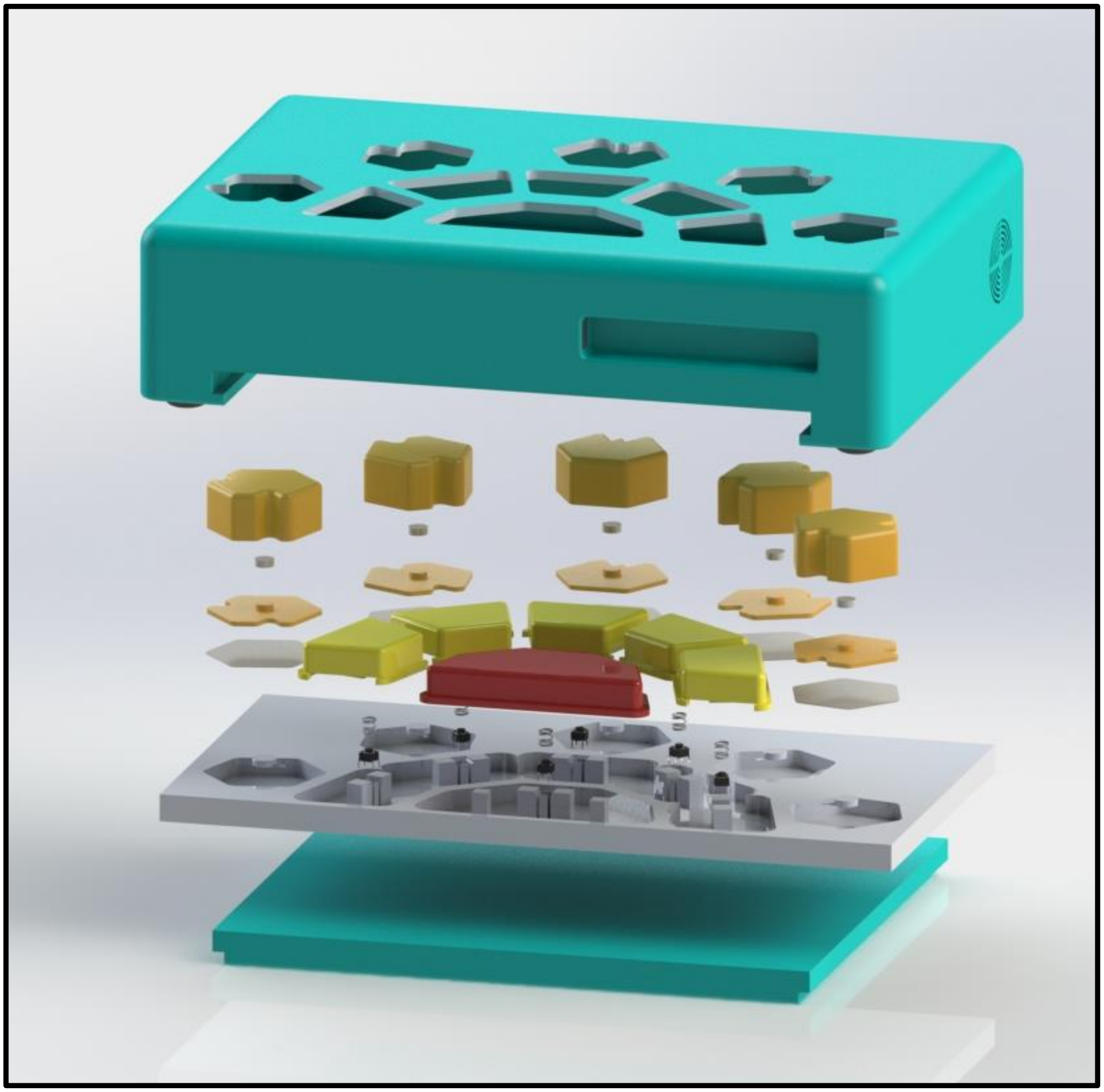
Story Mode Gameplay
#1: S&T story mode Introduction
Ex: "Welcome to the S&T vault! There are 5 Dinosaur tiles to discover, complete each dinosaur's challenge in order to unlock it's tile!" (Just an example)
#2: Player can then press any button (A)⟷(E) to trigger the corresponding "Tile Trial"
Ex: Player chooses (A)
(A) Dino #1 → Triggers minigame #1
(B) ... #2
(C) ... #3
(D) ... #4
(E) ... #5
same thing
(A) Minigame #1
(B) ... #2
(C) ... #3
(D) ... #4
(E) ... #5
If player successfully completes mini game, trigger corresponding tile prompt
Ex: Let (A) → Tri...
Player beats minigame
S&T then recites Tri... Prompt
#3: Once the player completes the 1st-4 minigames, the final boss round can now be triggered. (Maybe the 1st-4 buttons pressed can trigger any of the initial challenges, but final boss challenge can only be played if 4 were already done)
#4: Player completes final boss and wins the game
#5 (?): If player completes story mode without any mistakes, they can unlock a higher difficulty
Minigames Gameplay
(M) = Pause (During Gameplay) = Game Menu
Tac-Tiles!: Needs Work
Step #1: S&T recites trait about specific dino.
Ex: "3 Horns" → Triceratops
#2: Player should then have to feel around for the corresponding tile and hit correct button
#3: Player wins if they answer correctly for all dinos
Minigame #5: ?
Lightning Round:
Step #1: S&T recites a dino fact
#2: Player must choose dino that correlates with the previous fact
(A) Dino #1
(B) Dino #2
(E) Dino #5
Note: It'd be great to have mult. facts about each dino so we have options to cycle through
#3: Repeat steps 1-2 for remaining 9-Q's
#4: After all Q's are complete, you're given your final score out of 10.
Something's Fishy:
Step #1: S&T recites name of dino
#2: Player must press the button corresponding to the incorrect fact
(A) Fact #1 (D) Fact #3
(B) Fact #2 (E) Fact #4
(C) Incorrect
#2.5: Player chooses wrong answer → GAME OVER
Who Now?: Needs Work
Step #1: Remove all tiles
#2: S&T recites series of dino names
Ex: Triceratops, Pterodactyl, etc...
#3: Place the tiles corresponding to the order in which they were announced
Ex: Place Triceratops tile 1st, then the Pterodactyls, then...
#3.5: Player fails to place them in the correct order → GAME OVER
#4: Player correctly places the tiles and proceeds to next round
Note: Each round becomes more difficult as each additional round adds more dinos.
#3: Player choose correct answer and proceeds to next round
#5: Player wins when they choose the correct answer for all the dinos

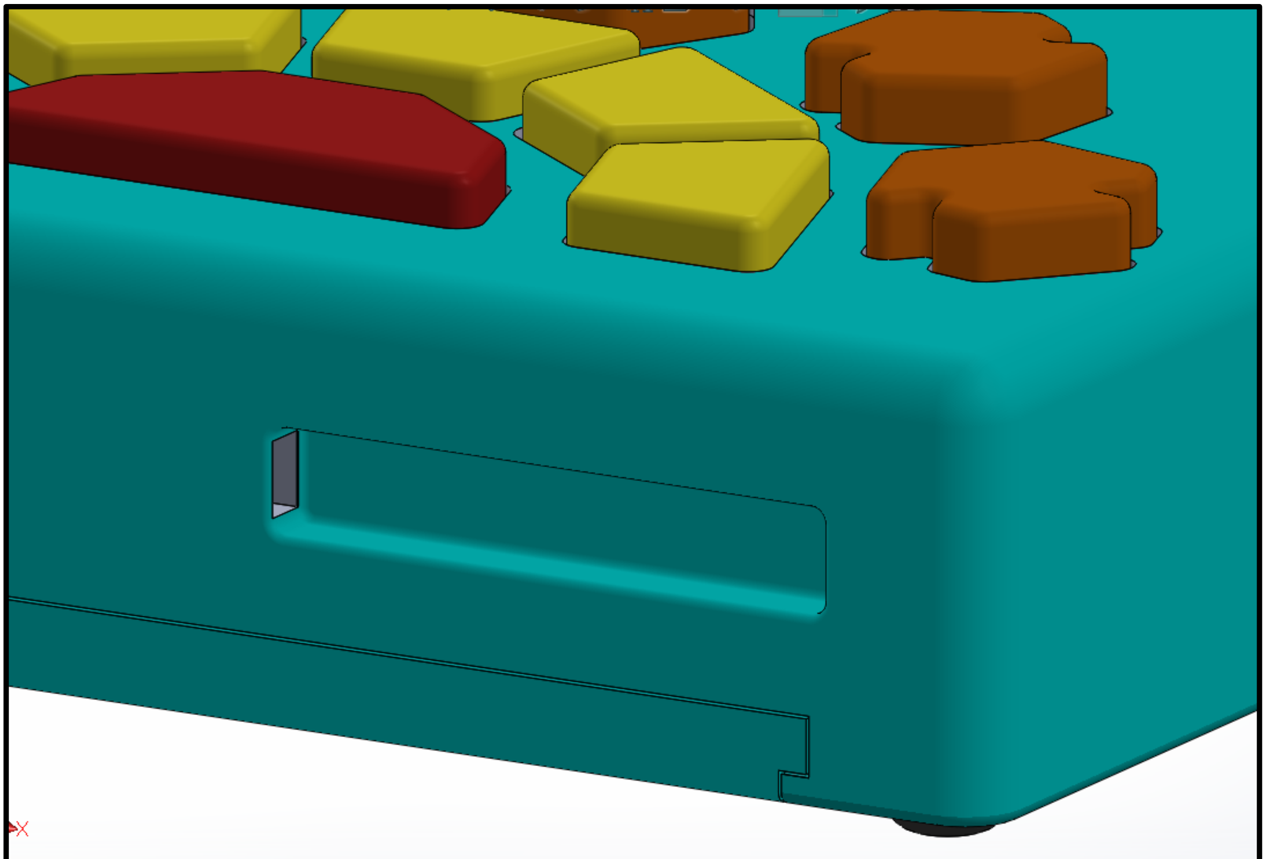

Launch "Minigames" → Minigame Menu
Ⓐ Minigame #1
Ⓑ . . . #2
Ⓒ . . . #3
Ⓓ . . . #4
Ⓔ Back to Main Menu
Ⓜ Launch
Minigame #1: Lightning Round
In this minigame you'll be put to the test as you have to match each dino fact given to the correct dino in order to earn points compete by yourself or with a friend to see who has the most dino brains!
Minigame #2: Who Now?
In "Who Now?" you'll be asked to 1st remove all the tiles and from there you'll hear a series of dino names from the show & tell. Using your Dino knowledge, place all the tiles in the correct order to progress and unlock the next difficulty.
phrases instead for higher difficulties
Minigame #3: Something's Fishy...
In this game you'll be given the name of dino and 5 facts, 1 for each button. However, 1 of these facts don't belong! Find the fake fact and move on to the next dino.
→ Maybe lower difficulties give 4 fake facts and 1 real, but the higher difficulty is as described above
Minigame #4: Tac-Tiles!
In the minigame tac-tiles there's 1 thing you have to keep in mind, textures! You'll be given a dinosaur characteristic (3 horns for example) and it's your job to investigate the tiles and choose the dinosaur that matches that trait.
Minigame #5:
There's a total of 5 dinos which means we need ~5 minigames, but it'd be broken if we didn't offer a "Back to Main..." button.
→ I was thinking that the last minigame in the story mode would act like a boss round, only playable by progressing through the "story"

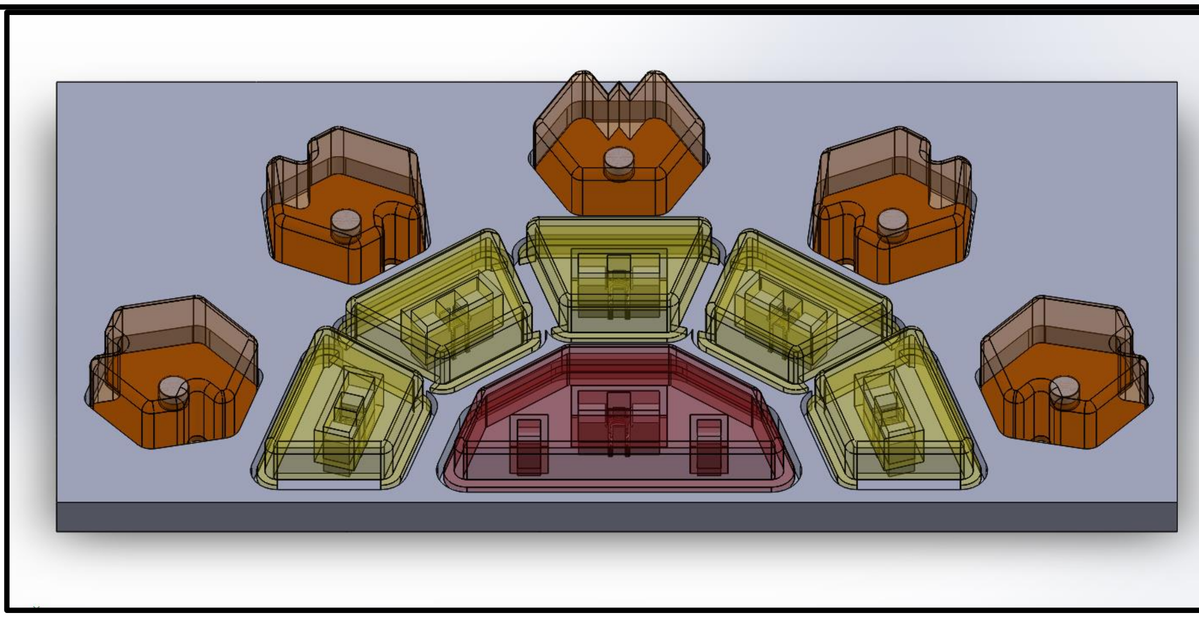

Gar
Launch "Dinosaurs"
→ Dinosaurs Menu:
Ⓐ Dinosaur #1
Ⓑ . . . #2
Ⓒ . . . #3
Ⓓ . . . #4
Ⓔ . . . #5
Ⓜ Back to main menu
→ Might be inconsistent to make Ⓜ the "back to main..." button, *potential adjustment
Hitting one of the buttons triggers the prompt available for the corresponding tile/dino
Ex: Let Ⓐ → Triceratops
Step #1: Hit Ⓐ
#2: S&T recites "Triceratops"
#3: S&T then recites info and fun facts that we've provided about the Triceratops
See Dinosaurs Info

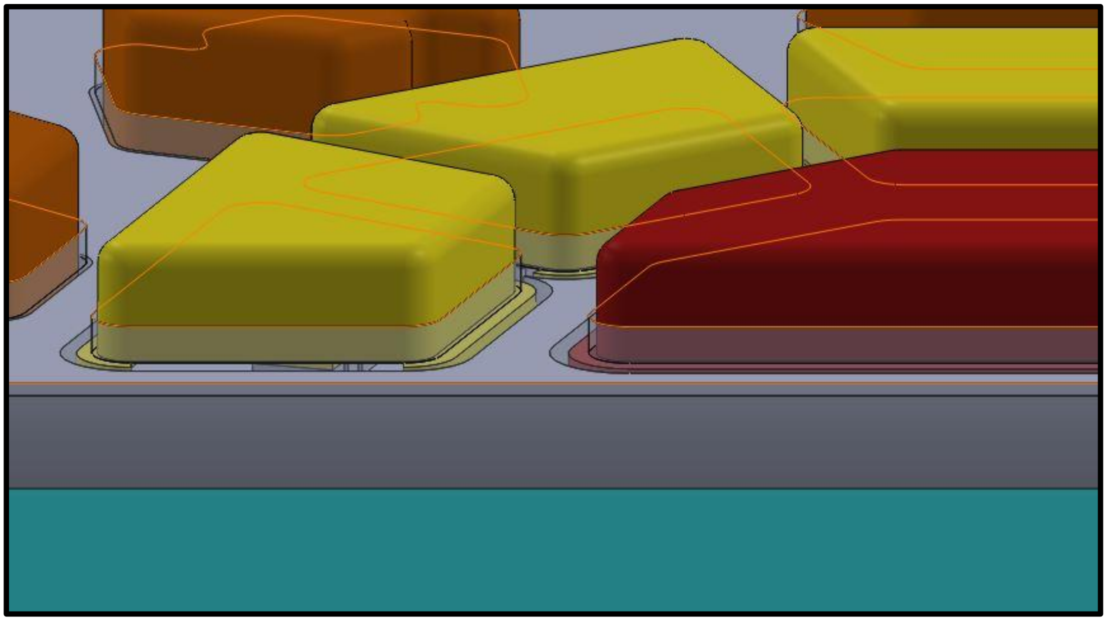
Appendix C

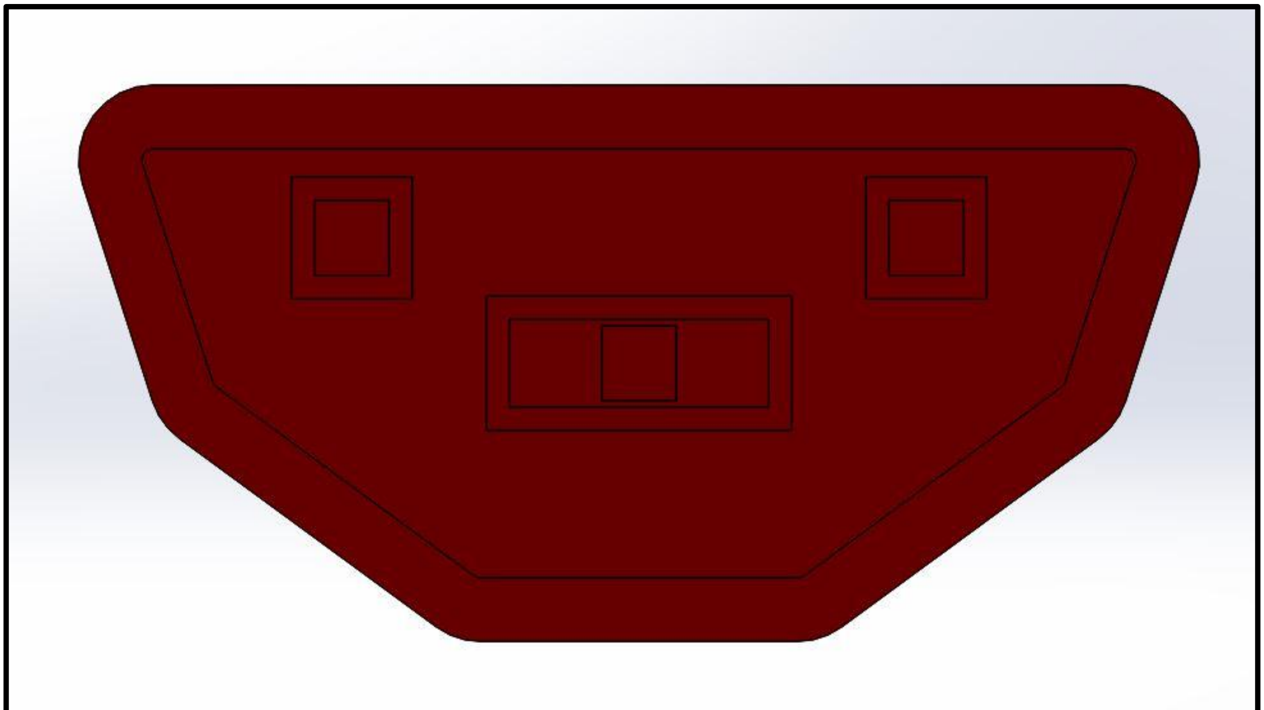
Show & Tell SolidWorks Models and Renders.

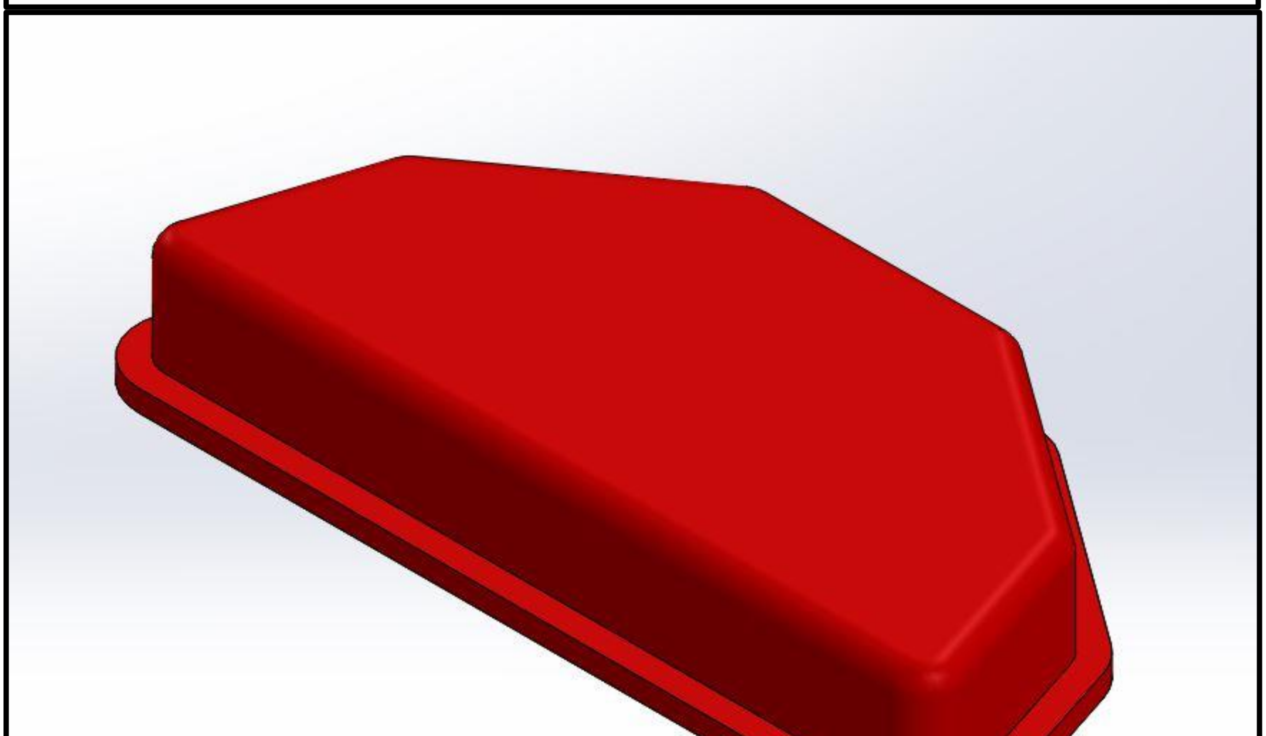


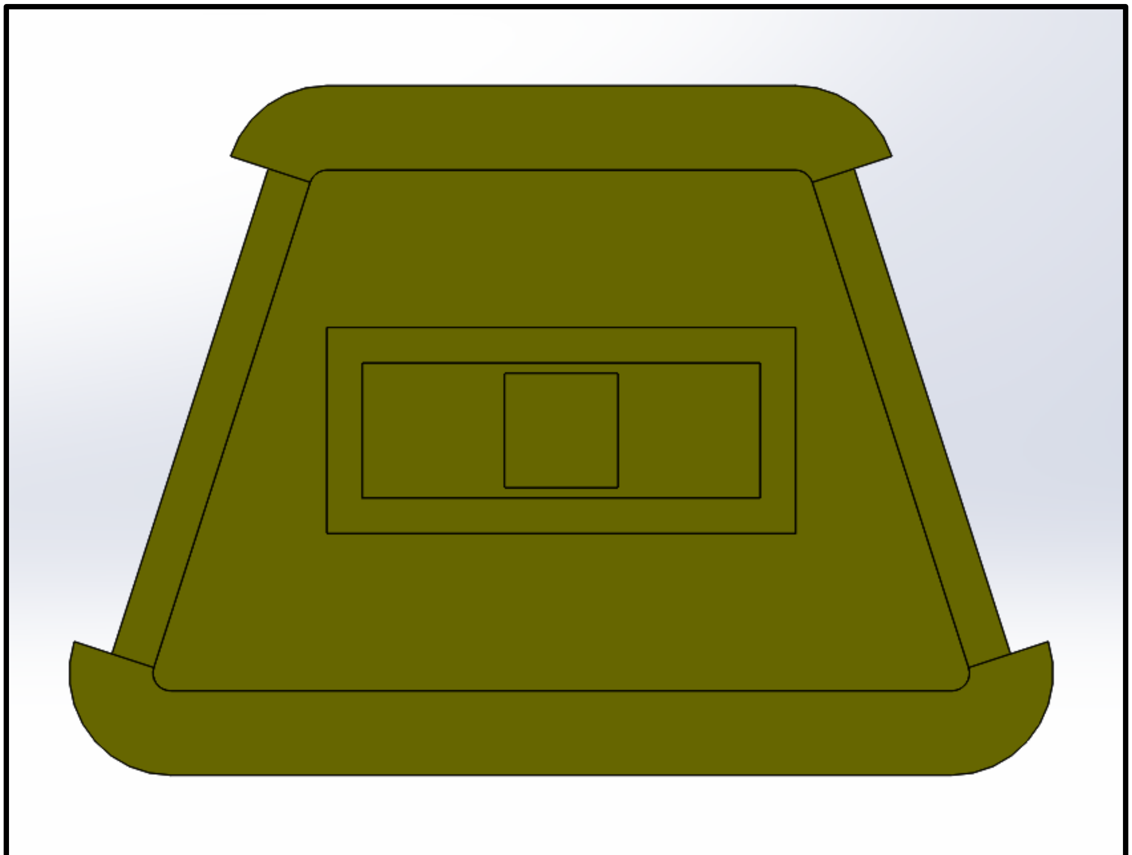


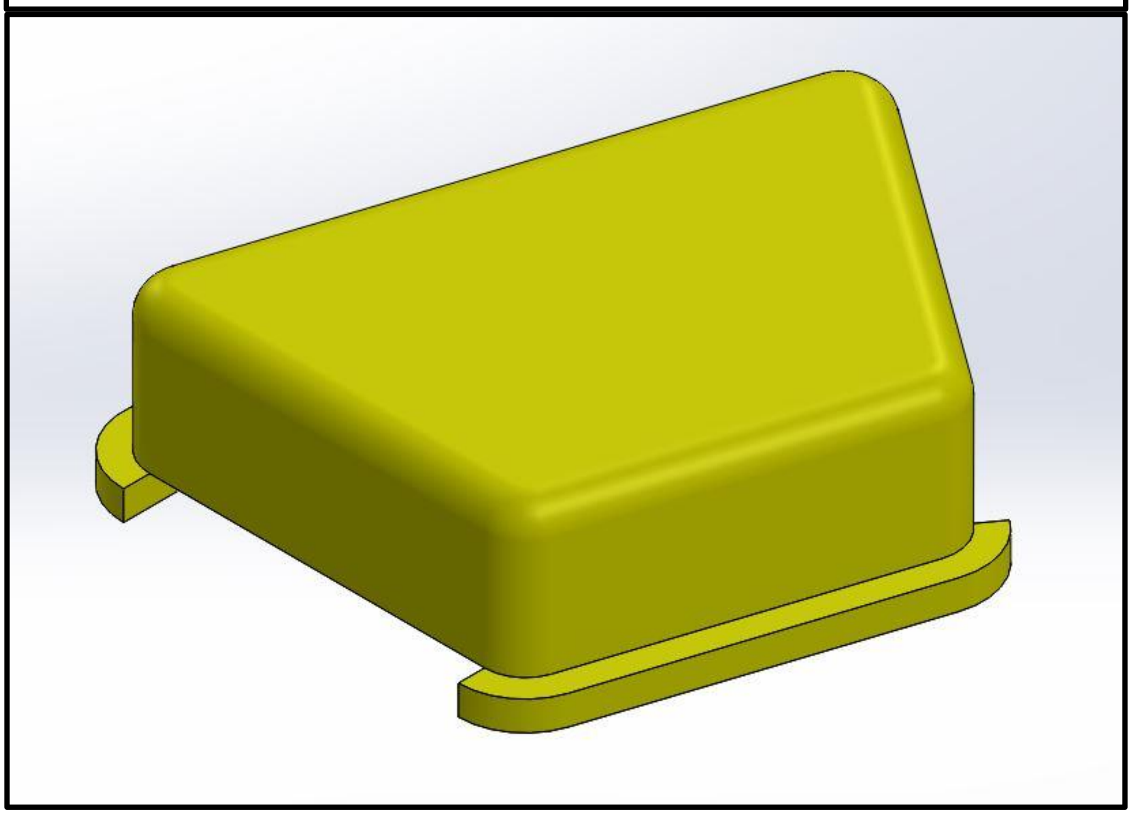


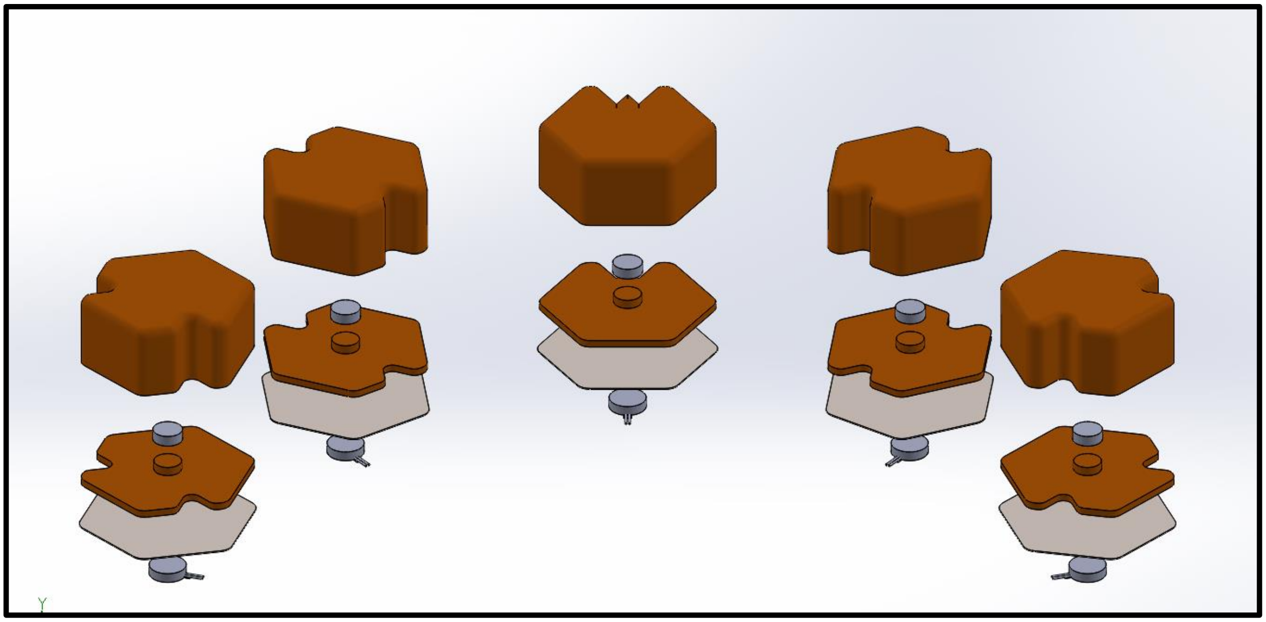












Appendix D

Production Estimates

	Print Name	Hours	:Minutes	
1	1 Tile Buttons	3	50	**Total**
2	4 Tile Buttons	9	5	**44.167 Hours**
3	2 Tiles	12	55	
4	3 Tiles	15	59	
5	Tile Caps A-E	2	21	

Item Name	**Supplier**	**Price (USD)**	**Quantity per price**	**Quantity Used**	**Cost of Material Used**
Tact Button Switch 6x6x5mm Pack of 100	Amazon	$6.80	100	6	$0.41
5Pcs 16mmx2mm 10K ohm Stereo Volume Control Wheel Potentiometer	Amazon	$5.45	5	1	$1.09
DC3V/0.1A 1.5V/0.05A 10x2.7mm Coin Mobile Phone Vibration Motor	Amazon	$9.88	10	5	$4.94
1/2" x 2' x 4' Birch Plywood	Home Depot	$21.97	8	3	$8.24

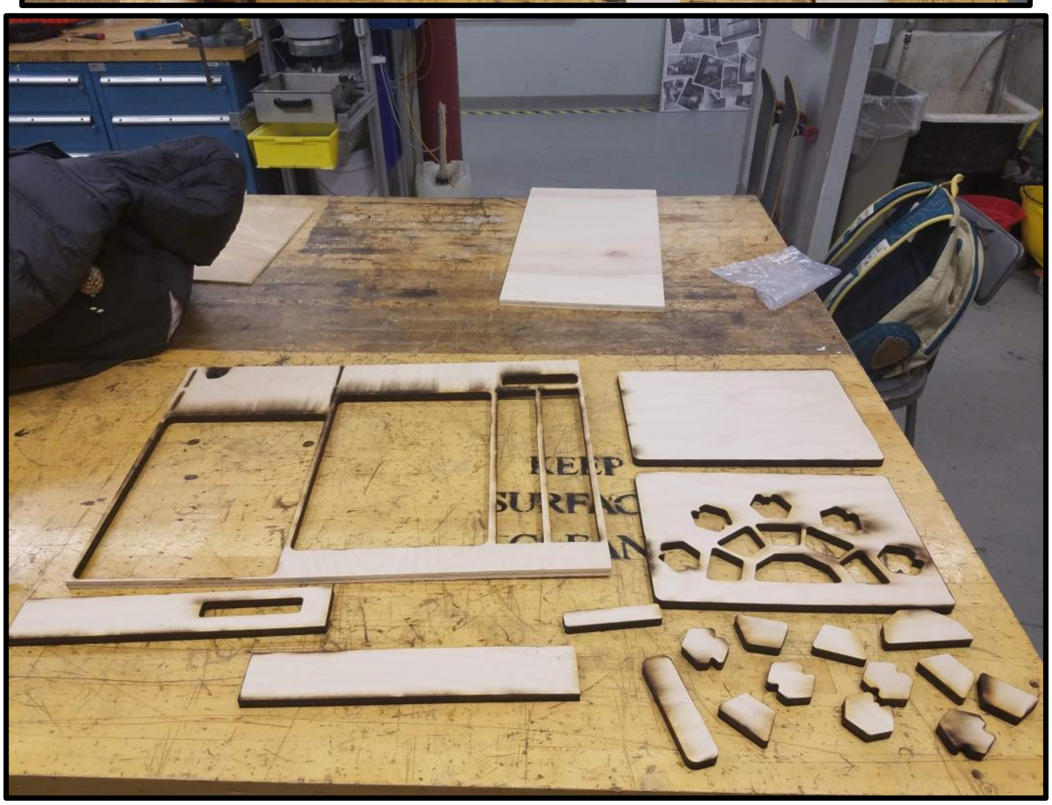
Sanded Plywood (5.2 mm x 2 ft. x 4 ft.)	Home Depot	$10.96	8	2	$2.74
Compression Spring, 302 Stainless Steel, Inch, 0.24" OD, 0.022" Wire Size, 0.127" Compressed Length, 0.25" Free Length, 1.99 lbs Load Capacity, 16.24 lbs/in Spring Rate (Pack of 10)	Amazon	$8.08	10	6	$4.85
Adafruit Wave Shield for Arduino Kit	Amazon	$23.80	1	2	$23.80
Arduino Uno R3 Microcontroller	Amazon	$19.99	1	1	$19.99
Speaker - 0.5W (8 Ohm)	Sparkfun	$1.95	1	2	$3.90
				Subtotal	$69.95
Massachusetts sales tax				6.25%	$4.37
				Total	$74.33

	Material Cost (USD)	Production cost (USD)	Tooling Cost (USD)	Injection Molding Cost (USD)
Base Unit (1000)	$12,386.00	$2,779.00	$27,784.00	$42,950.00
(per part)	$12.29	$2.78	$27.78	$42.95
Tile Button	$282.00	$1,487.00	$6,015.00	$7,784.00

(5000)				
(per part)	$0.06	$0.30	$1.20	$1.56
Central Button (1000)	$94.00	$475.00	$7,660.00	$8,229.00
(per part)	$0.09	$0.48	$7.66	$8.23
Button Tray (1000)	$1,798.00	$2,309.00	$18,207.00	$22,313.00
(per part)	$1.80	$2.31	$18.21	$22.31
Tile A (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Tile B (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Tile C (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Tile E (1000)	$215.00	$945.00	$5,582.00	$6,742.00
(per part)	$0.22	$0.95	$5.58	$6.74
Total (1000 units)	$15,435.09	$10,839.64	$82,071.18	$108,346.02
total (per unit)	$15.44	$10.84	$82.07	$108.35

Appendix E

Construction of prototypes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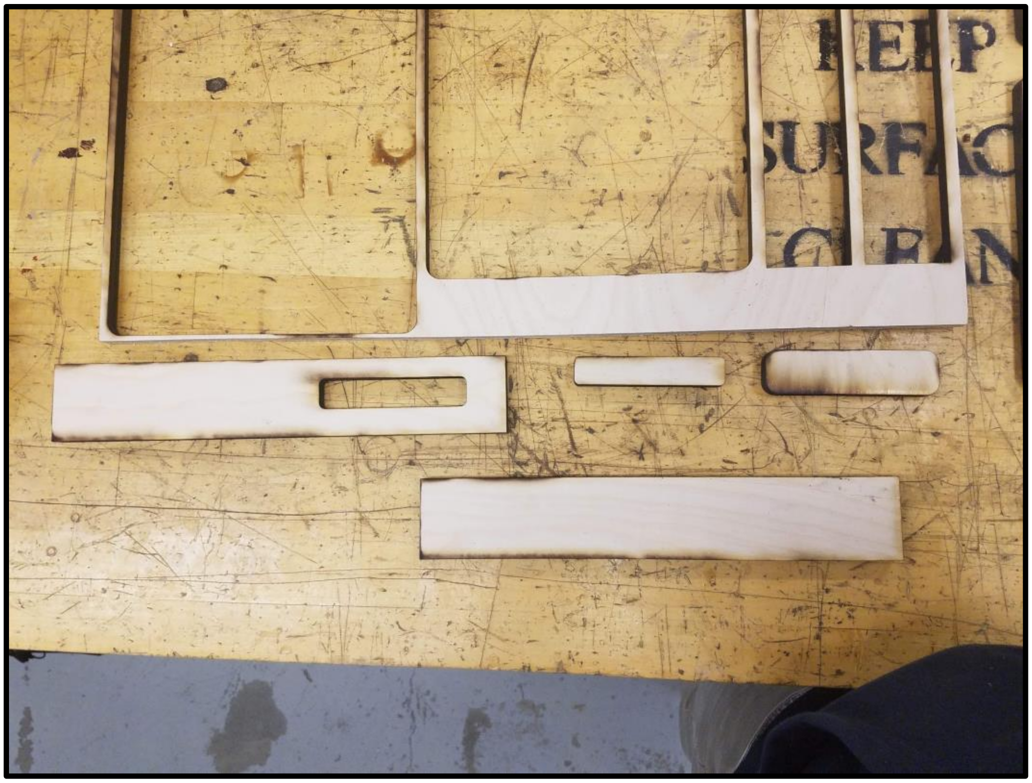
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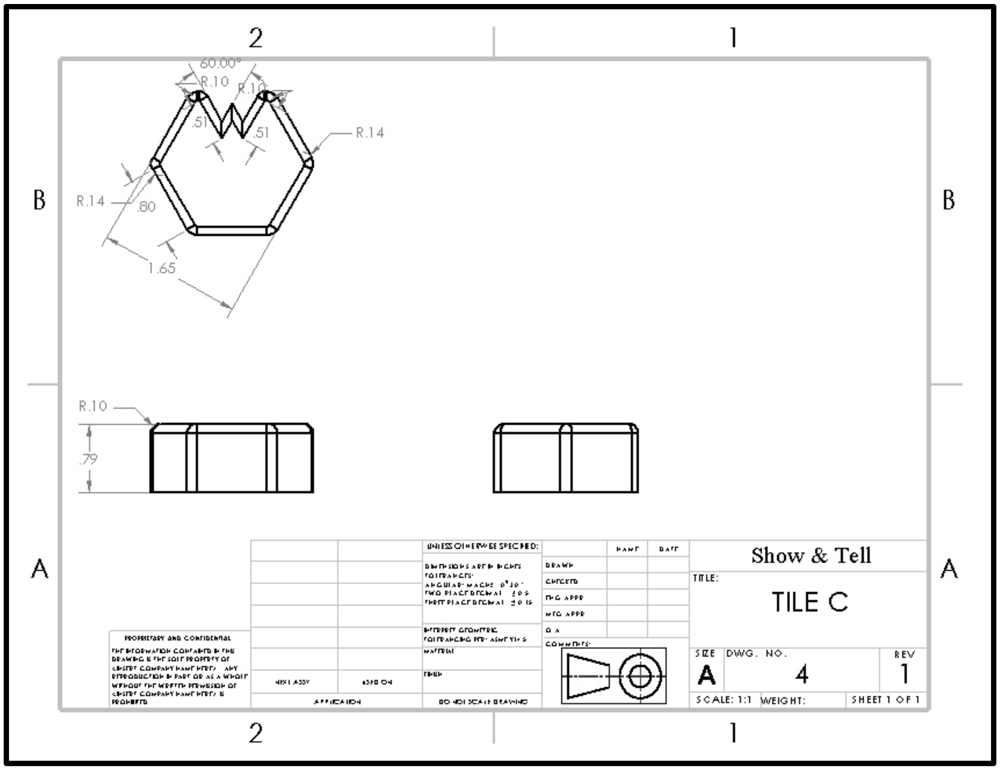
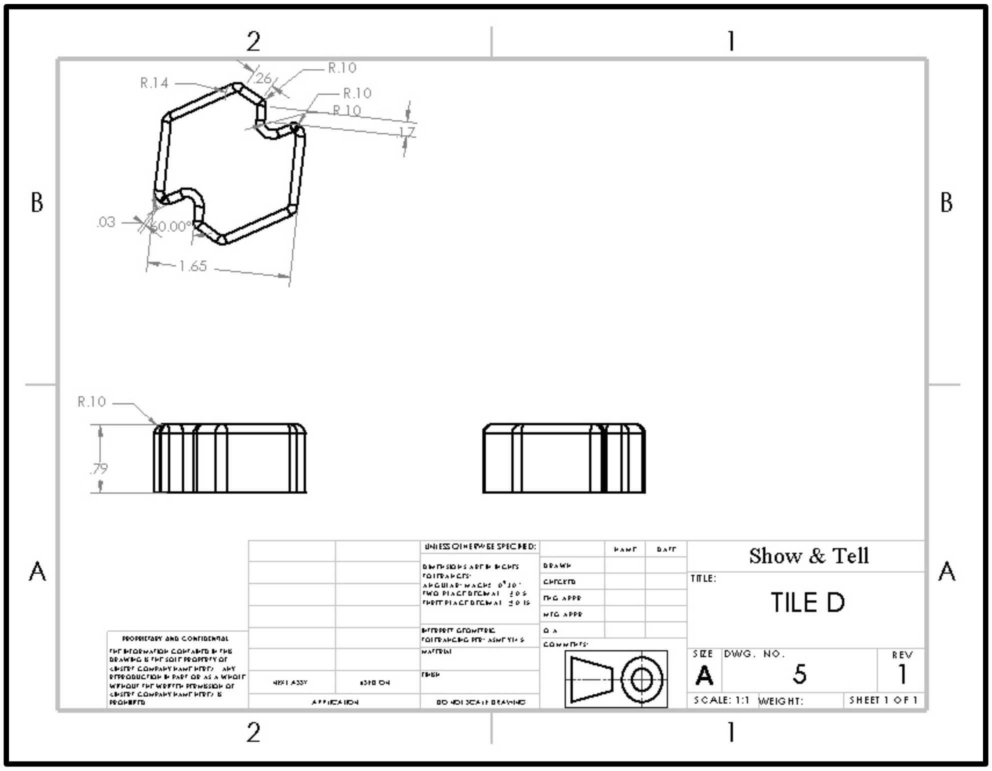
Appendix F

Final Prototype

Appendix G

Drawings




R.14
.26
R.10
R.10
R.10
.17
.03
60.00°
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R.10
.79
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
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CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
FINISH
NAME
DATE
Show & Tell
TITLE:
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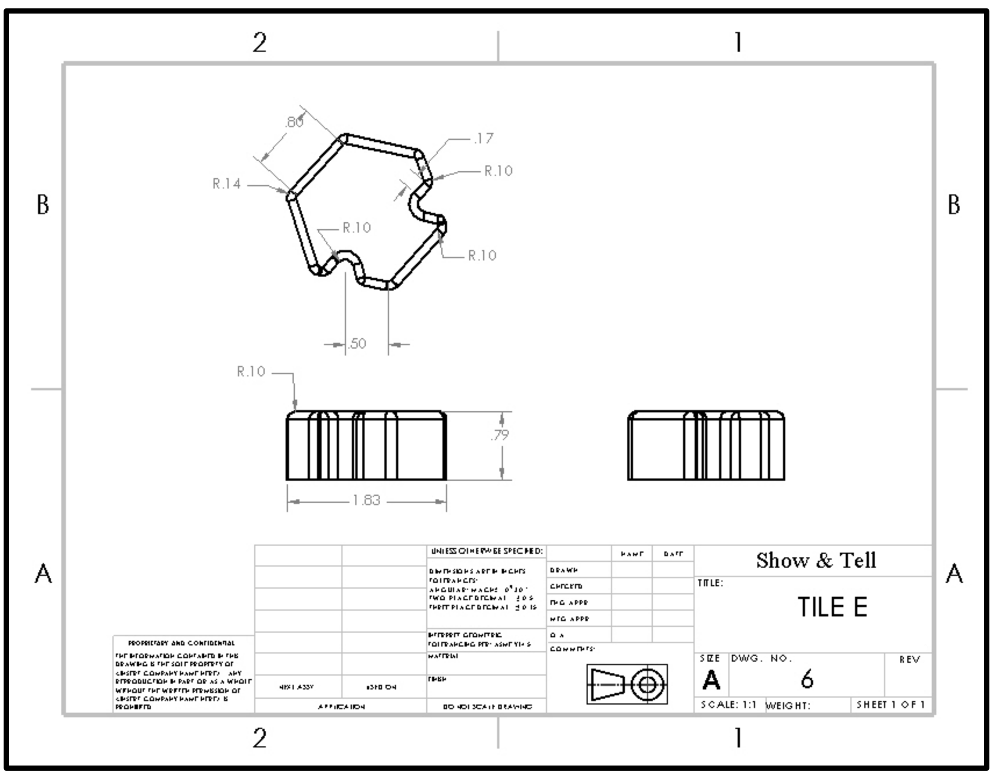
SIZE
A
DWG. NO.
5
REV
1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1


.80
.17
R.14
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UNLESS OTHERWISE SPECIFIED:
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APPLICATION
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MFG APPR.
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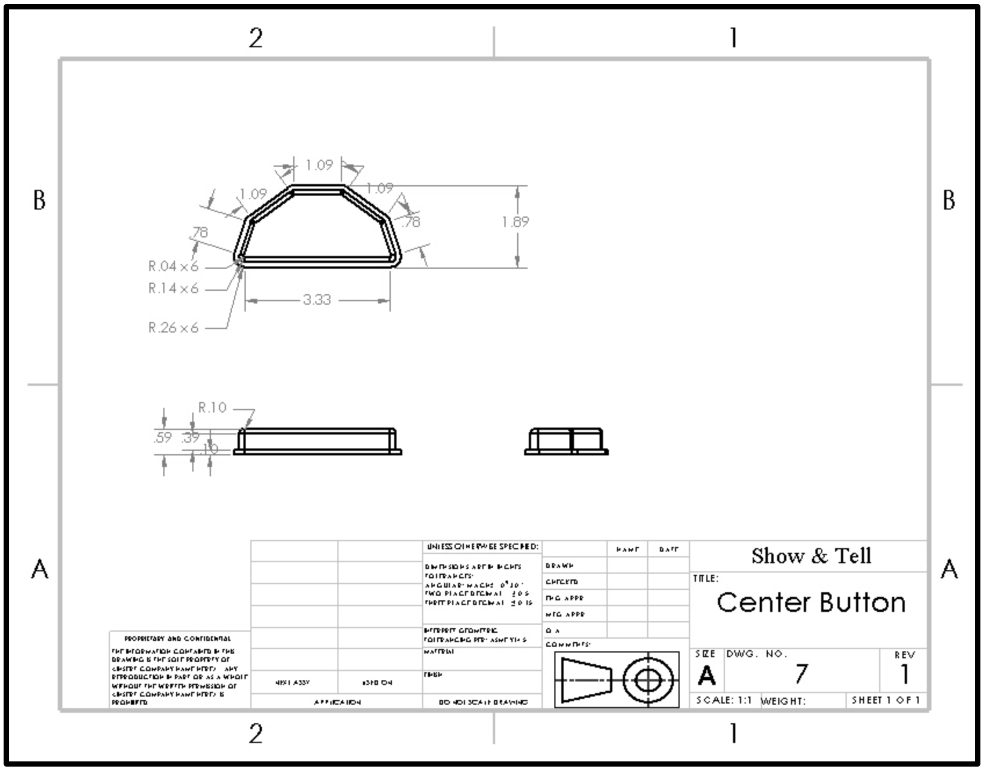
COMMENTS:
MATERIAL
FINISH
NAME
DATE
Show & Tell
TITLE:
TILE E
SIZE
A
DWG. NO.
6
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1



1.09
1.09
1.09
.78
.78
1.89
R.04×6
R.14×6
3.33
R.26×6
R.10
.59
.39
.10
UNLESS OTHERWISE SPECIFIED:
Show & Tell
TITLE:
Center Button
SIZE
A
DWG. NO.
7
REV
1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
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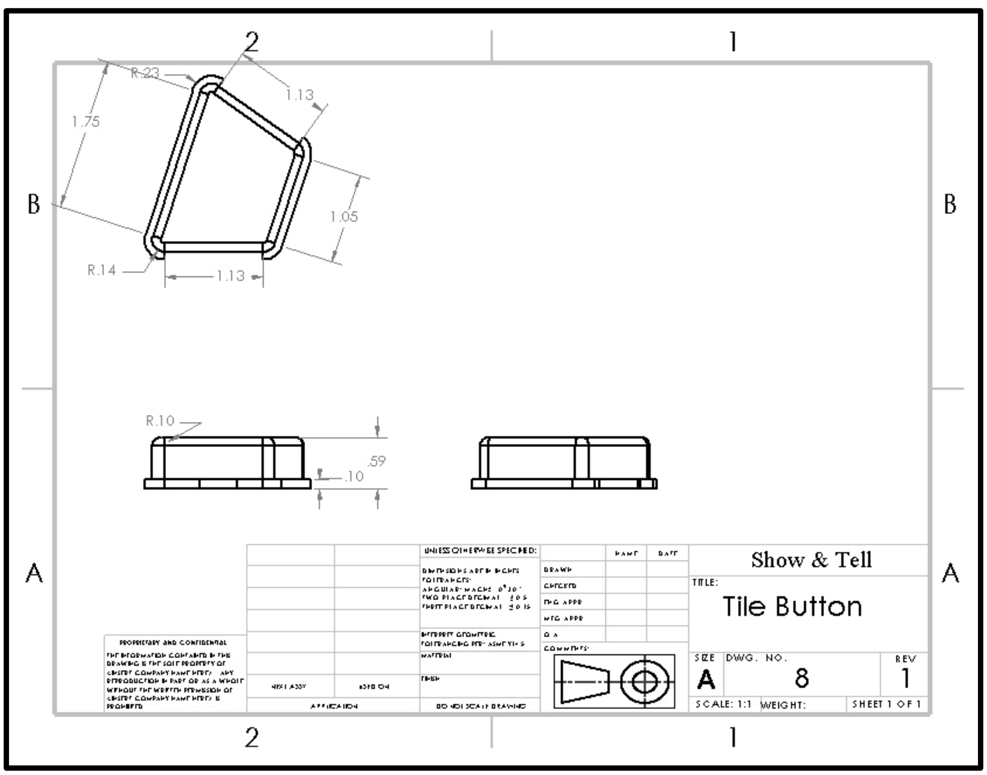


R.23
1.13
1.75
1.05
R.14
1.13
R.10
.59
.10
UNLESS OTHERWISE SPECIFIED:
Show & Tell
TITLE:
Tile Button
SIZE
A
DWG. NO.
8
REV
1
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
DO NOT SCALE DRAWING

Appendix H

Toy Questionnaire #1

4/25/2018 Toy Questionnaire #1

Toy Questionnaire #1

For our MQP, we would like to ask your opinion concerning the statements and questions below

* Required

1. **As a child, what was the reason why you liked your favorite toy?** *
   Mark only one oval.
   - Visual Appeal
   - Tactile Appeal
   - Popular Media Reference
   - Price
   - Function

2. **Were you more attracted to toys that referenced popular childhood media?** *
   Mark only one oval.
   - Yes
   - No

3. **Does competition make toys and games more enjoyable?** *
   Mark only one oval.
   - Yes
   - No

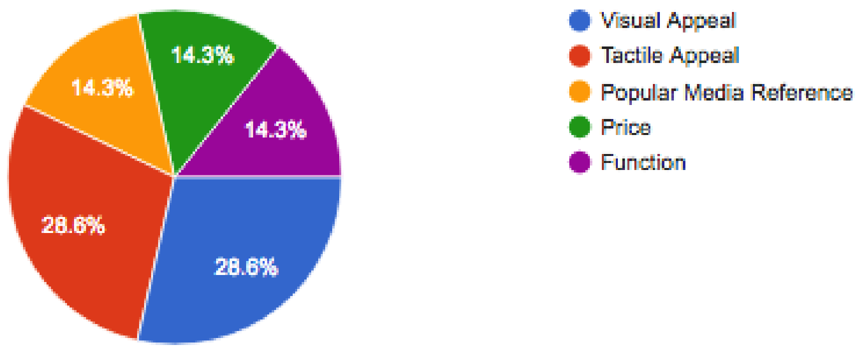
4. **What do you think the target age is? (years)** *
   Mark only one oval.
   - 2 - 6
   - 6 - 10
   - 10 - 14
   - 14 - 18

5. **How much would you expect to pay for this toy?** *
   Mark only one oval.
   - $0 - $20
   - $20 - $40
   - $40 - $60
   - $60 - $80
   - $80 - $100
   - > $100

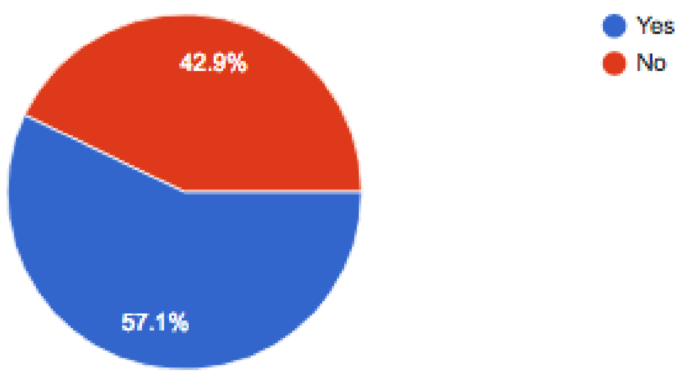
https://docs.google.com/forms/d/1i11iEdxYJmUtBUCv0B6gk1uF7pYa7ngBZuDlrlMmgAQ/edit 1/2

Toy Questionnaire #1 - Results

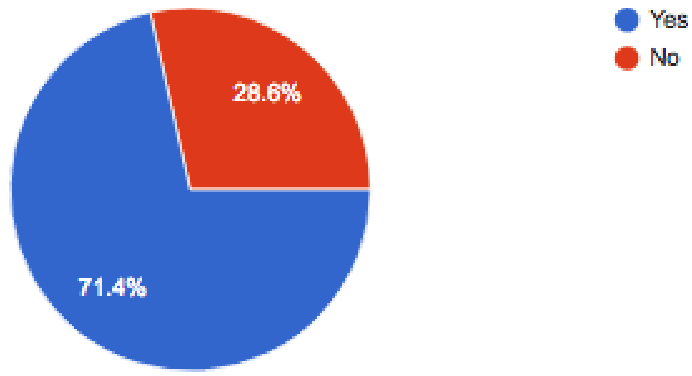
As a child, what was the reason why you liked your favorite toy?



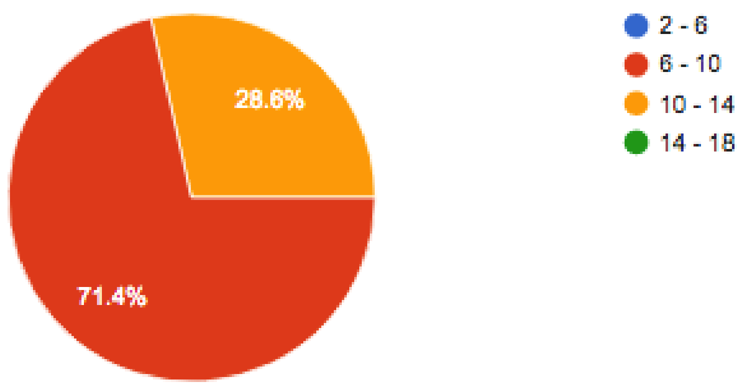
Were you more attracted to toys that referenced popular childhood media?



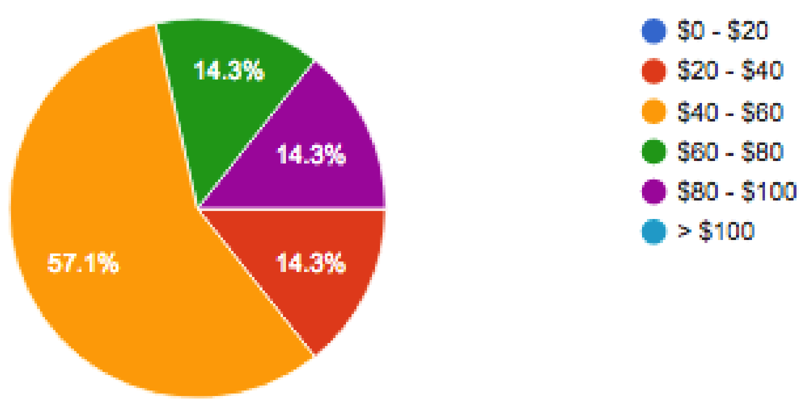
Does competition make toys and games more enjoyable?



What do you think the target age is? (years)



How much would you expect to pay for this toy?



Toy Questionnaire #2

Toy Questionnaire #2

1. **"The Show & Tell is a unique concept that I believe people need."**
Mark only one oval.
- ◯ Strongly Agree
- ◯ Agree
- ◯ Disagree
- ◯ Strongly Disagree

2. **How do you feel about our our pricing structure?**
Mark only one oval.
- ◯ Very reasonable
- ◯ Reasonable
- ◯ Unreasonable
- ◯ Very unreasonable

3. **If you played the game with your eyes open, how do you feel about the statement: "I had a fun time, and would be willing to play another Play Pack in that sitting."**
Mark only one oval.
- ◯ Strongly Agree
- ◯ Agree
- ◯ Disagree
- ◯ Strongly Disagree

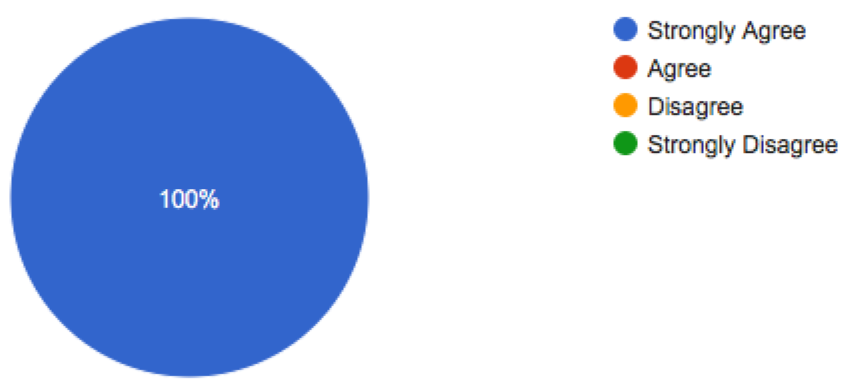
4. **Were you able to insert a flash drive into the Show & Tell with your eyes closed on the first time?**
Mark only one oval.
- ◯ Yes
- ◯ No

5. **If yes, were you able to do it in less than 15 seconds?**
Mark only one oval.
- ◯ Yes
- ◯ No

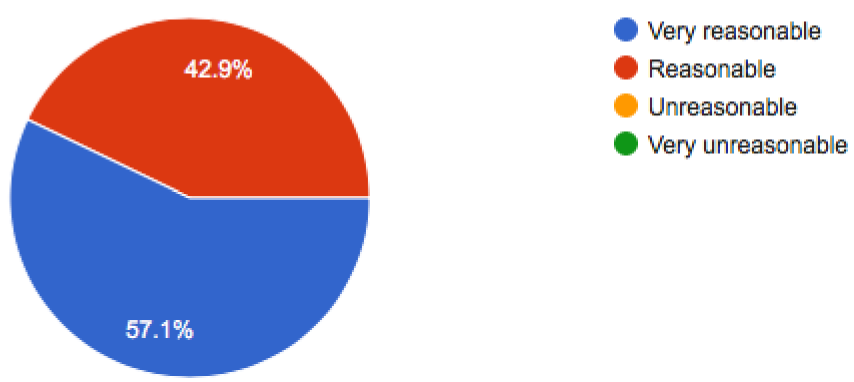
6. **Could you feel a difference between different braille sentences?**
Mark only one oval.
- ◯ Yes
- ◯ No

Toy Questionnaire #2 - Results

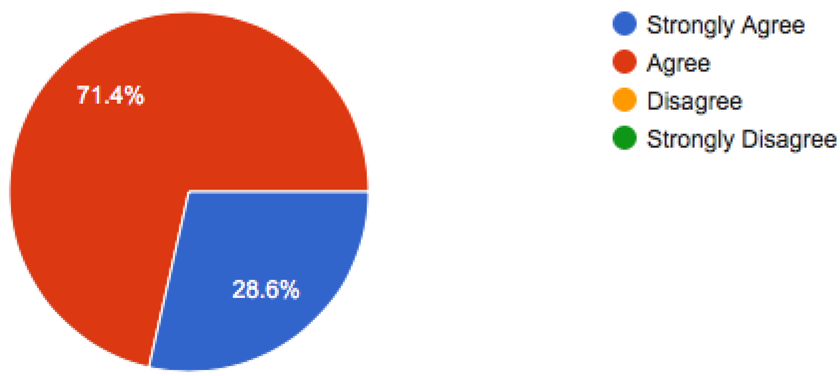
"The Show & Tell is a unique concept that I believe people need."



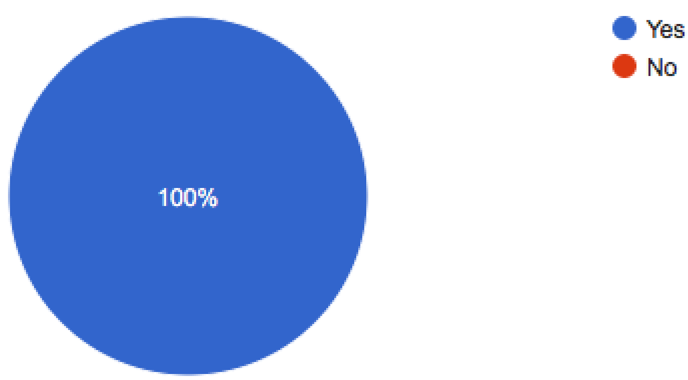
How do you feel about our our pricing structure?



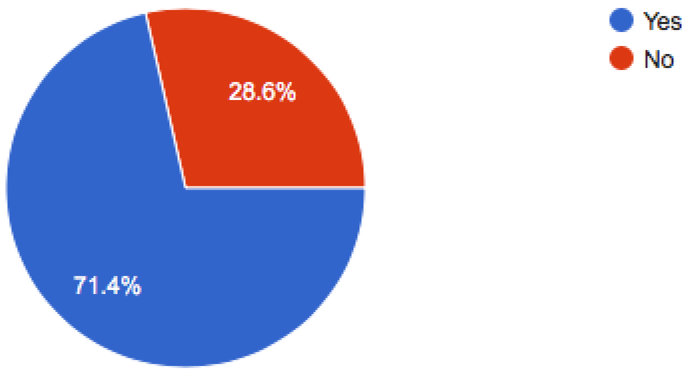
If you played the game with your eyes open, how do you feel about the statement: "I had a fun time, and would be willing to play another Play Pack in that sitting."



Were you able to insert a flash drive into the Show & Tell with your eyes closed on the first time?



If yes, were you able to do it in less than 15 seconds?



Could you feel a difference between different braille sentences?